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CYCLONES AND ANTICYCLONES SOUTH OF 50° SOUTH

U. S. NAVY WEATHER RESEARCH FACILITY
BUILDING R-48, U. S. NAVAL AIR STATION
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REVIEWED AND APPROVED

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FOREWORD

This report is based upon an investigation conducted under Task 16, "Polar Weather Analysis and Forecasting Techniques."

A survey of the literature, carried out prior to the initiation of this study, showed that some information concerning the frequency of occurrence of cyclones and anticyclones in the Southern Hemisphere was available. Unfortunately, most of this information pertained to rather small areas and, for the most part, was based upon rather short data periods.

Because of the difficulties involved in attempting to summarize the results of previous studies carried out by several different investigators, an independent study was conducted, incorporating the most recent data available and encompassing the Southern Hemisphere south of 50° S.

The synoptic charts used in this study may be somewhat questionable, due to the scarcity of weather observations over much of the Southern Hemisphere. However, the results presented in this report should be useful to the weather officer assigned to the area by providing him with information not available to him in the past.

This publication was written by Mr. Gene D. Prantner, Task Leader of Task 16, and was edited by Mr. John M. Mercer.

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1. INTRODUCTION

The weather officer assigned to duty with the U.S. Navy Antarctic Support Forces is faced with several difficult problems. Some of the more serious obstacles to a successful forecast for the antarctic region include: (a) a scarcity of weather reporting stations, (b) an expanding area for which accurate forecasts are needed, and (c) the extraordinary communication difficulties frequently encountered.

Forecasting for operations south of 50° S. should improve after the relatively large amount of meteorological data, that has been collected during the past decade, has been summarized and evaluated. This type of data evaluation is necessary since previous investigations were based on data of comparatively short duration and pertinent to a rather small area; consequently, relatively little is known about the occurrence, behavior, and structure of weather systems affecting the area south of 50° S.

1.1 Purpose

The purpose of this publication is to present the results of a study of the percentage frequency of occurrence of surface pressure systems on a monthly and seasonal basis. Although based upon the best available Southern Hemisphere surface synoptic charts, the results should be regarded as tentative due as much to the uncertainties of analysis over the tremendous expanse of the southern oceans and the continent of Antarctica as to the short period (6 years) for which surface charts were available.

Nevertheless, this study provides some information which should be useful in improving both the analysis and forecasting of meteorological events of importance to naval units operating south of 50° S.

Throughout this publication Antarctica shall refer to the continent proper, while "southern oceans" pertains to that part of the Southern Hemisphere between 50° S. and the northern coast of Antarctica. The entire region between 50° S. and 90° S. will be referred to as the "Antarctic", or as "antarctic regions".

1.2 Procedure

Surface synoptic charts from several sources [11, 18, 28] were used in obtaining the results presented here. In a manner similar to that used by Petterssen [22] and Reed and Kunkel [23], the entire Southern Hemisphere south of the 50th parallel was divided into sectors or "squares" by means of a square grid measuring 5° of latitude on a side. On the basis of one chart per day, the total number of occurrences of low or high pressure centers within a given square during a particular period (month or season) was determined and divided by the total number of days in the period to obtain the percentage frequency of occurrence. The percentages were then isoplethed by assuming that they varied linearly between adjacent squares.

Since the isopleths of percentage frequency for a given month or season refer to average conditions over a 6 year period, the lowest and highest percentage of low centers observed throughout the period is included for each month to aid in interpretation.

It should be noted that on the basis of the technique just described, no definitive statements can be made as to whether an area of maximum percentage frequency of occurrence of low or high pressure centers is due to a single semi-permanent system in the area or due to the passage of many migratory systems across the boundaries of the area.

1.3 Mean Sea Level Pressure

The most recently published charts of the Southern Hemisphere mean sea level pressure for the midseason months of January, April, July, and October [29] are reproduced in figures 1.1, 1.2, 1.3, and 1.4, respectively. The periods of record upon which these charts are based are 1951 through 1957 for January and April, and 1951 through 1956 for July and October.

Included among the features of interest exhibited by these mean charts are the trough of low pressure circling the continent between 65° S. and 70° S. latitudes, the progressive movement to the south of the trough from January to October, the movement of a pressure minimum into the Ross Sea area from the northeast accompanied by a decrease of central pressure during the same time period, and the existence of a mean low pressure area in the Weddell Sea in October.

The sea level analysis does not extend very far inland, due to the high elevation of much of the Antarctic continent above mean sea level.

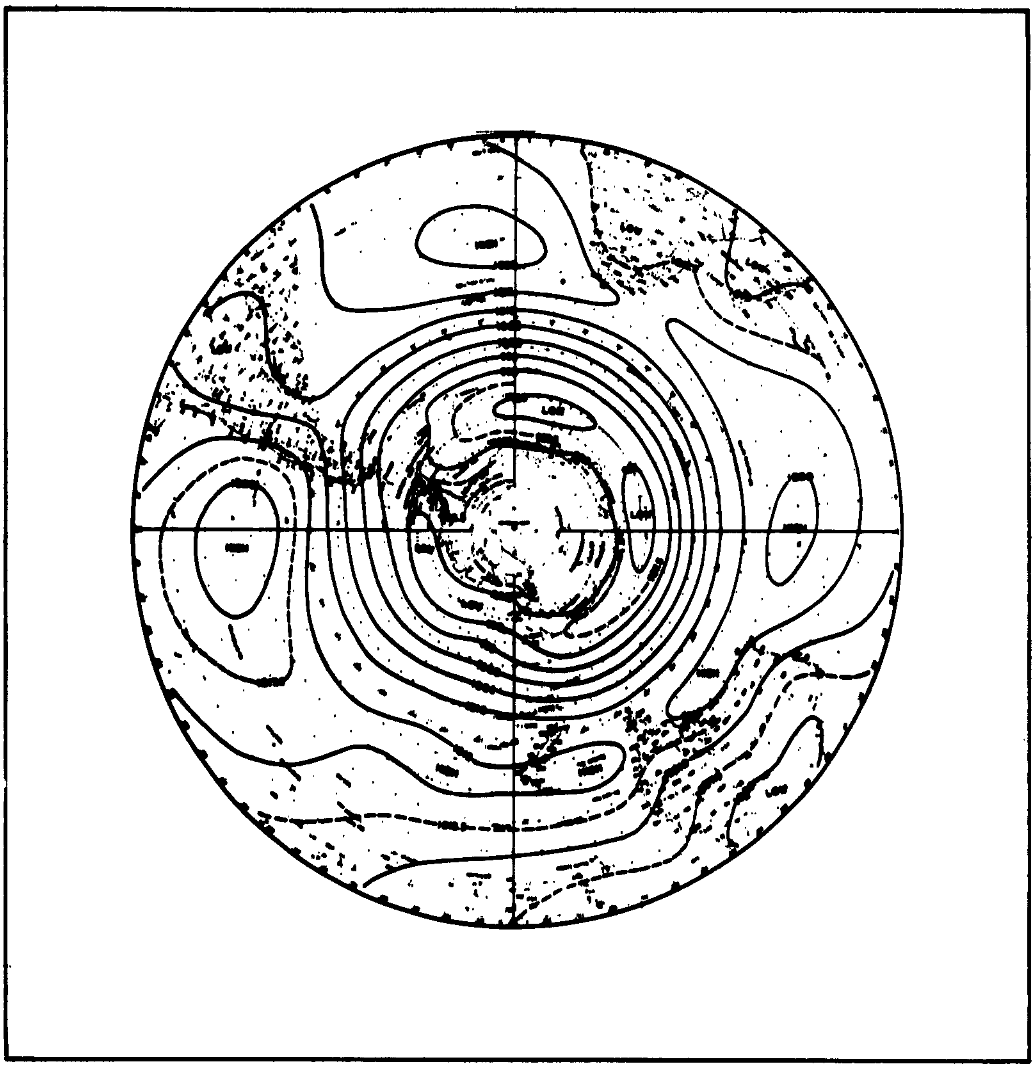


Figure 1.1. January Mean Sea Level Chart (mb.) of the Southern Hemisphere South of 15°S. [29].

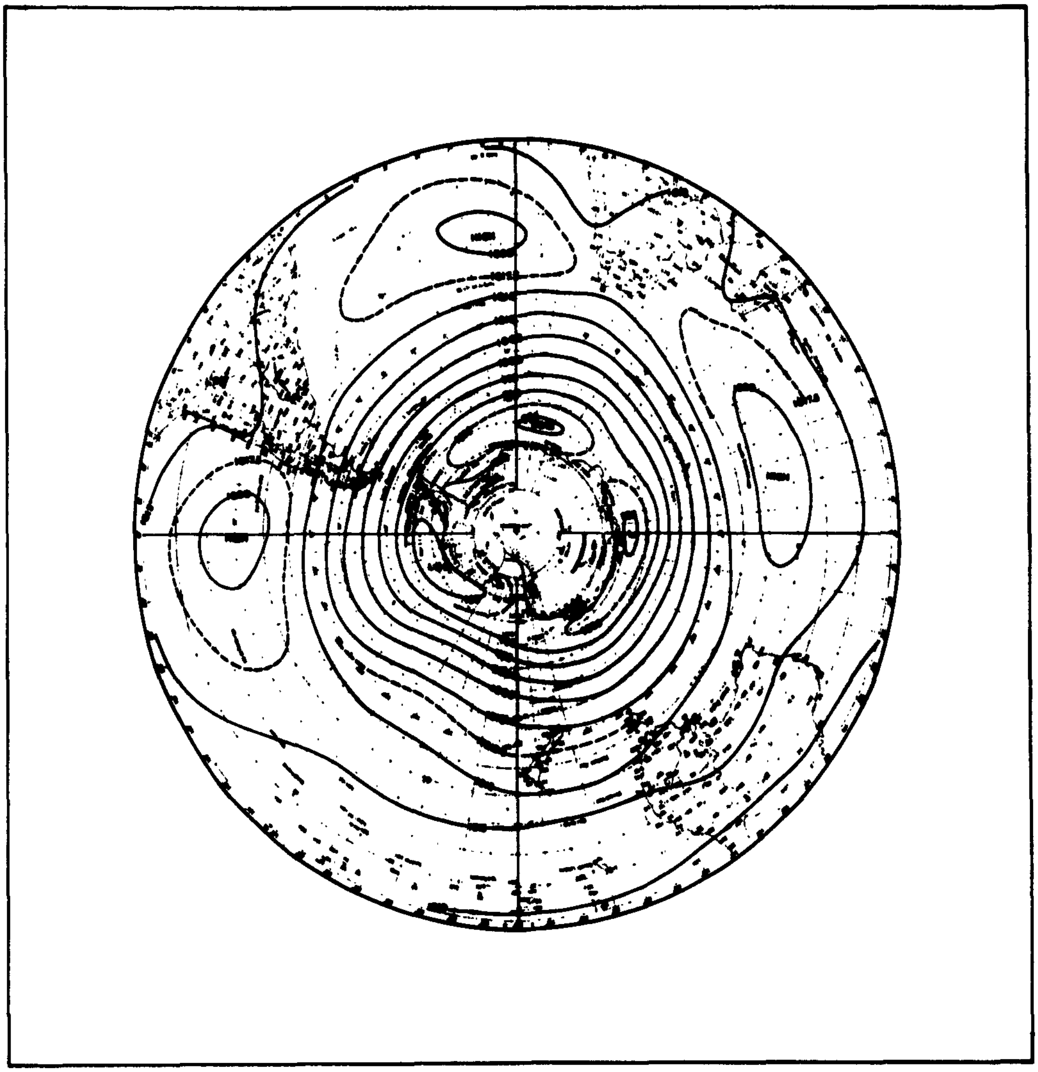


Figure 1.2. April Mean Sea Level Chart (mb.) of the Southern Hemisphere South of 15°S. [29].

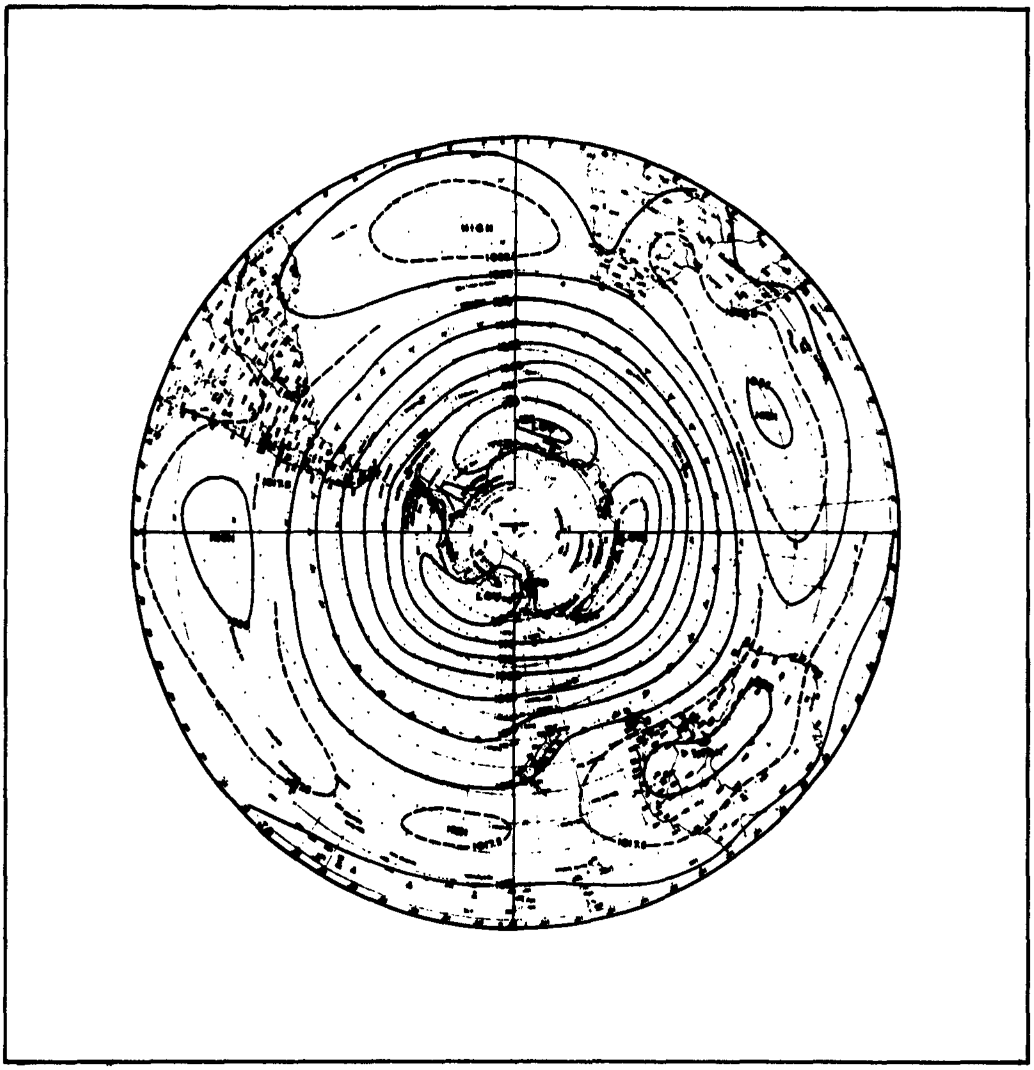


Figure 1.3. July Mean Sea Level Chart (mb.) of the Southern Hemisphere South of 15°S. [29].

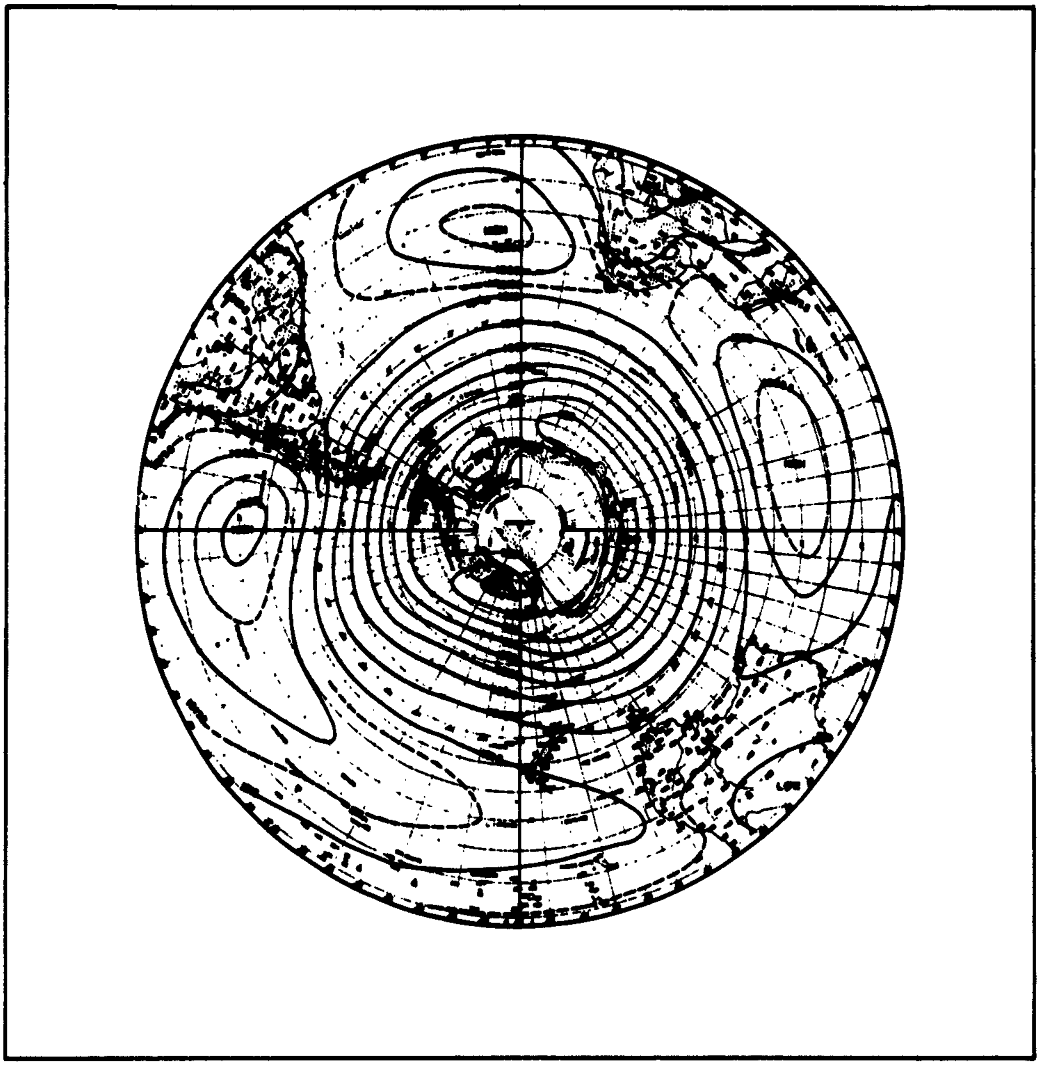


Figure 1.4. October Mean Sea Level Chart (mb.) of the Southern Hemisphere South of 15°S. [29].

2. CYCLONES

2.1 Historical Review

The existence of a circumpolar trough or region of minimum pressure at about 60° S. had been established by the end of the first decade of this century [5, 21]. The ensuing 35 years were largely devoted to the development of theories of Southern Hemisphere circulation--in which the intensity, location, and behavior of the circumpolar trough and its associated migratory pressure systems played an important part. In later years, Langford [16] confirmed that, on the basis of data for the period December 1954 through March 1955, a trough of low pressure at about 60° S. is an almost permanent feature of the Southern Hemisphere circulation. Alt, et al [2], noted this trough of low pressure in 1959 and Gibbs [6] incorporated it into a proposed model upon which to base the analysis of synoptic charts over the southern oceans.

The monthly and seasonal variations with latitude of the subantarctic trough has received much attention in the last 10 years. Using data for January and July 1949, Gibbs [7] found that the region of maximum occurrence of cyclones was between 55° S. to 60° S. in winter (July) and between 60° S. to 70° S. in summer; this agrees with a study of late summer and fall conditions during 1947 and 1948 by Lamb [15].

Van Loon [30] found that, during the summer seasons of 1955 through 1957, "...the trough lies, in the mean, further south in the South Pacific than in the South Atlantic and Indian Oceans. In the Pacific Ocean the axis of the trough runs from 67° S. in the Bellingshausen Sea to 75° S. in the northeastern Ross Sea. In the two other oceans it lies between 60° S. and 65° S."

Substantially the same conclusion was reached by Holcombe [10]. His study, based on a large amount of data, indicated that although the seasonal shift of the mean latitude of the zone of maximum cyclone frequency in the Southern Hemisphere is rather small (1.9°) it definitely is found at higher latitudes in summer (February) than in winter (August).

The above mentioned results are opposite to those obtained by Hofmeyr [9] in his study of the mean surface pressure in the Southern Hemisphere. He found that the circumpolar trough was displaced slightly to the south and deeper in July than in January, reaching its southernmost location and greatest intensity in October. This view is supported by Krichak [14], who maintains that winter cyclones occur nearer to the continent than the summer ones. Mirabito [20] reached the same conclusion based on personal experience as a Navy meteorologist during Deep Freeze operations.

A third viewpoint, shared by Astopenko [3] and Karelsky [12], maintains that there is little or no change in location of areas of maximum cyclonic activity over the subantarctic oceans during the year.

2.2 Percentage Frequency of Occurrence of Low Centers

The month to month variation of the average total number of daily accumulated low centers occurring throughout the Southern Hemisphere, south of the 50th parallel, is portrayed in figure 2.1. The maximum for any one month occurred during December, with secondary maxima occurring in March and August. September has the lowest average number of low centers. Although these months represent extreme conditions, the difference between September and December is relatively small when expressed as a percentage of the average number of low centers occurring throughout the year, being 3.1 percent (with 7.0 percent for September and 10.1 percent for December).

The variation from season to season (fig. 2.2) of the average number of occurrences south of 50° S. is, of course, even less than the monthly variation and is more regular. The summer months (December, January, February) contain the largest number of occurrences followed in decreasing order by fall (March, April, May), winter (June, July, August), and spring (September, October, November). The seasonal variation in the percentage frequency of the number of low centers occurs as follows: 26.3 percent of them occur in summer with the fall, winter, and spring figures being 26.1 percent, 24.4 percent, and 23.2 percent, respectively. Thus, although cyclones are, on the average, more frequently observed south of 50° S. during the summer than during the other three seasons, there is a difference of only 3.1 percent between the seasons of maximum and minimum occurrences.

This study indicates that although there is some probability of observing cyclonic activity during any given month throughout the area south of 50° S. latitude (except perhaps for certain regions of the Antarctic Continent itself) there are

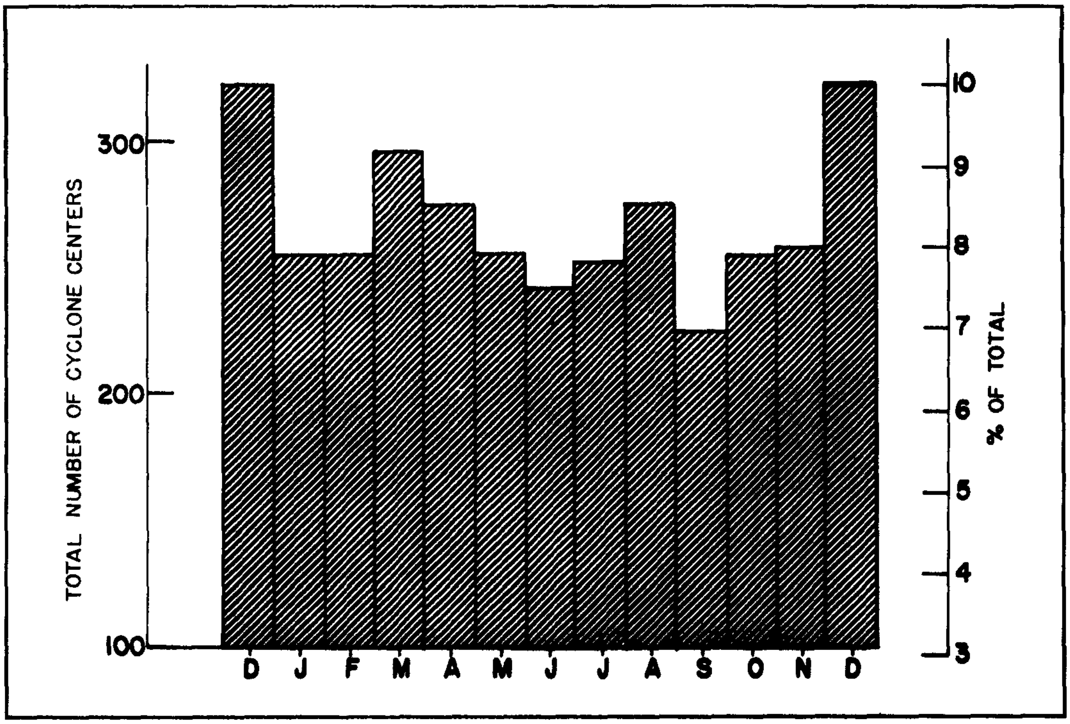


Figure 2.1. Average of the Total Number of Cyclone Centers, Accumulated from Daily Surface Weather Charts, South of 50°S. Latitude by Month. August 1948 through December 1952 and January 1960 through August 1961.

several well defined regions where a relatively large percentage of the total number of low centers is observed.

The following regions have been defined for use in this study. Region I (fig. 2.3) is situated between 0° and 50°E. longitude. Region II extends from approximately 50° E. longitude (southwest of Iles de Kerguelen) to 160° E. (southwest of New Zealand). The Ross Sea sector, extending eastward from Cape Adare to the vicinity of 100°W. longitude, will be referred to as region III. The areas north of the Bellingshausen and Weddell Seas comprise regions IV and V, respectively. The Antarctic Continent, although not a region of maximum cyclonic activity, will be referred to as region VI for purposes of discussion.

Throughout the following discussion the monthly and seasonal variations of cyclonic activity are based upon several factors; namely, (1) the area enclosed by the 6 percent isopleth of percentage frequency of occurrence of low centers, (2) the magnitude of the maximum percentage frequency observed throughout a particular region, and (3) the position of the axis or "ridge" of maximum percentage frequency of occurrence as implied by the isopleth analysis. In the case of region VI, the Antarctic Continent, the area enclosed by the 2 percent isopleth will be utilized as a basis for discussion.

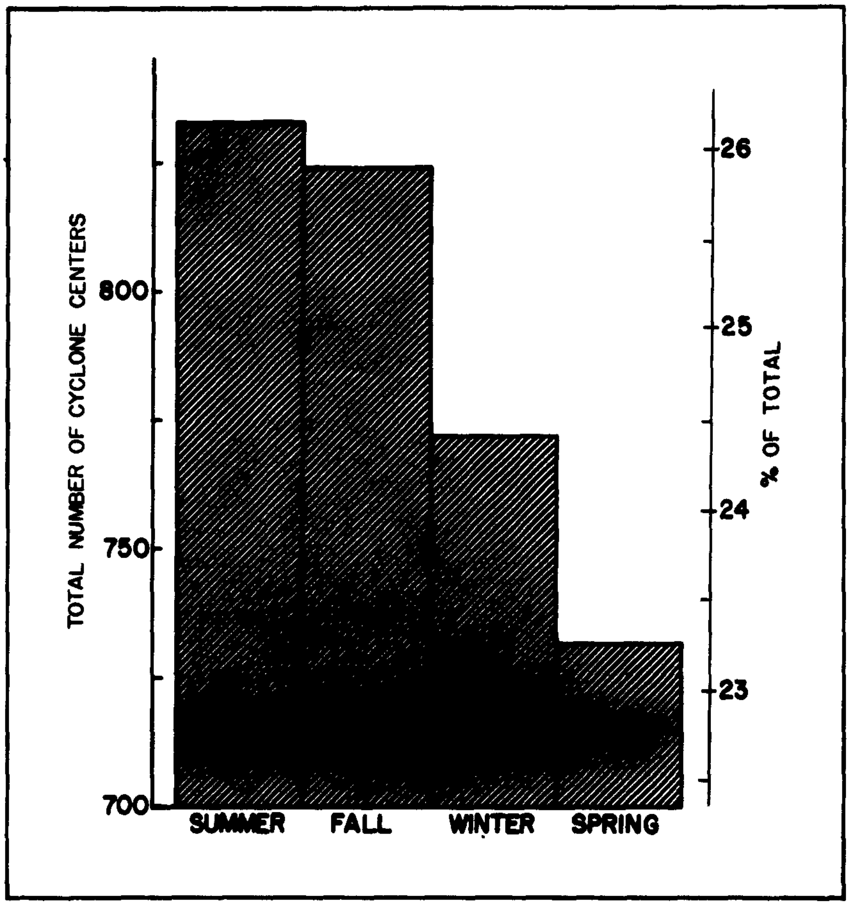


Figure 2.2. Average of the Total Number of Cyclone Centers, Accumulated from Daily Surface Weather Charts, South of 50° S. Latitude by Season.

The discussion included in sections 2.2.1 through 2.2.6 is based upon figures 2.4 through 2.31, which follow the text of this chapter.

2.2.1 Region I (0° to 50° E. Longitude)

The percentage frequency of occurrence of low centers observed in this region reaches a maximum during March, at which time the center of cyclone activity has reached its southernmost position in the vicinity of Lutzow-Holm Bay, at about 70° S. As the fall season progresses the centers of maximum frequency of occurrence shift to the north, being located at about 64° S. during April and at about 62° S. during May. Coincident with this shift to more northerly latitudes, as winter approaches, there is a definite decrease in the maximum percentage frequency of occurrence of low centers within the region.

In the eastern part of region I the area of maximum cyclonic activity is displaced southward during the winter months (June, July, August). However, the average location of maximum cyclonic activity throughout the winter season is slightly north of its location during fall, 65° S. as opposed to 67° S. Essentially the same remarks could be made concerning the western part of the region near 10° E. longitude, except that the shift from month to month is somewhat erratic.

Throughout the whole of region I the percentage frequency of occurrence of low centers is

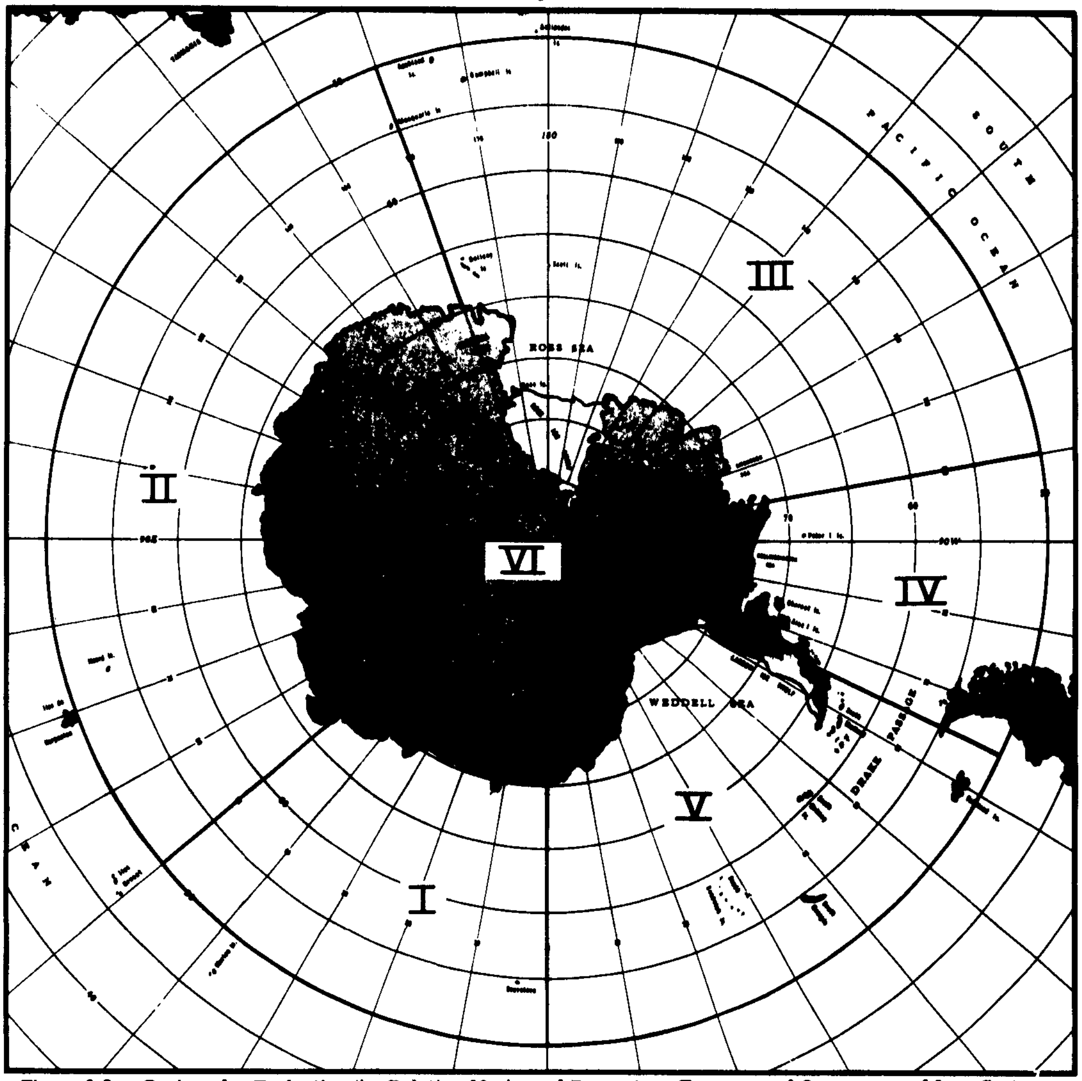


Figure 2.3. Regions for Evaluating the Relative Maxima of Percentage Frequency of Occurrence of Low Centers.

less in winter than in fall, with a winter minimum occurring during August.

Cyclone activity diminishes to a yearly low during spring and the center of maximum shifts equatorward, so that in November (the end of the spring season) it is located at about 62° S. The average position of the center of maximum occurrence of low centers throughout the region during spring is some 2° to the north of the average winter position.

Cyclone activity in region I is slightly greater in summer than in spring and, although there is no significant latitudinal shift in the average seasonal location of the area of maximum occurrence, there is a noticable shift in longitude of approximately 5° to the west.

2.2.2 Region II (50° E. to 160° E. Longitude)

Throughout the year there appear to be three favored locations for the occurrence of low centers in this region. One center of cyclonic activity is located at about 75° E. longitude, just south of Heard Island. Another concentration of low centers is apparent near 105° E., and the third favored location of low centers is southwest of MacQuarie Island in the vicinity of 150° E. longitude. Since the seasonal shifts of these centers of cyclonic activity are quite similar they will not be discussed separately, but each center of cyclonic activity will be regarded as being typical of the entire region.

During March the axis of maximum frequency of occurrence of low centers is farther poleward than at any other time of the year, as well as being of greatest magnitude. The zone of maximum frequency of occurrence of cyclone centers is found progressively farther north as fall terminates and winter begins, with the most northerly winter position occurring during June near 60° S. latitude. During July and August the centers of cyclonic activity tend to shift slightly poleward, although the average winter position of the area of maximum activity is slightly north of its latitudinal position during fall. The frequency of occurrence of low centers decreases to a seasonal minimum during spring. This is also the season when the average position of maximum cyclonic activity is found farthest north. This northward shift in position of the area of maximum cyclone activity with season (from summer through fall, winter, and spring) is definite though small in magnitude, 3° or 4°. Except for the distinct minimum in spring, the longitudinal extent of the area of maximum frequency of occurrence of low centers, as evidenced by the area enclosed by the 6 percent isopleth, does not change much from season to season.

2.2.3 Region III (160° E. to 100° W. Longitude)

Within this region there are two important zones of cyclonic activity. The primary zone is roughly bounded by 145° W. and 180° longitude, and the other region of cyclonic activity, referred to hereafter as the secondary zone, is located to the northwest of the Amundsen Sea between the latitudes of 61° S. and 71° S.

The center of maximum percentage frequency of low centers in the primary zone of region III is located in its most northerly position near 64° S. latitude in late spring (November). From November through April the center of activity shifts in a rather regular fashion to its most southerly position near 74° S. Coincident with this poleward movement of the center of cyclone activity, from late spring to the middle of fall, there occurs a twofold increase in magnitude of the maximum percentage frequency observed. The center of activity during the month of May is located a few degrees to the north of the April position and exhibits the largest percentage frequency of occurrence of any month. There is little latitudinal change in location of the area of maximum percentage frequency of low centers during the months of June, July, and August, although a longitudinal shift to the east is noted during these 3 months.

An area of maximum percentage frequency of occurrence of low centers appears in the vicinity of Scott Island during the month of July but is not evident during the other winter months of June and August.

From August to September the area of maximum cyclone activity shifts slightly equatorward and approximately 10° to the west, and decreases in magnitude. This decrease in cyclone activity continues through October, during which a minimum number of low centers are observed in the zone.

On a seasonal basis, the center of maximum cyclone activity in the zone is located near 62° S. during spring, its most northerly position throughout the year. The percentage frequency of occurrence of low centers is also at a minimum at this time. Cyclone activity reaches a seasonal maximum in fall at which time it is also located in its most southerly position--near 72° S. There is little change in the position of the center of activity from fall to winter, although there is a noticeable decrease in the maximum percentage frequency of occurrence of low centers. This primary zone of region III is similar to region I, in that the center of maximum cyclonic activity progresses equatorward more during the summer months than during the winter.

The zone of secondary maximum in region III exhibits essentially the same seasonal movements as noted in the primary zone, although not as well defined. The isopleths of percentage frequency of occurrence of low centers in the secondary zone are regarded with less confidence than most of the other areas discussed, due to the almost complete lack of observing stations within this zone.

2.2.4 Region IV (Bellingshausen Sea)

The monthly maximum percentage frequency of occurrence of low pressure centers takes place in early summer (December) in the Bellingshausen Sea region and is located near 62° S. latitude, its most northerly position throughout the year. From then until mid-autumn (April) it moves to more southerly latitudes in a fairly regular manner. During the remainder of the year the center of cyclonic activity appears in latitudes between the extremes of December and April, 62° S. and 67° S. latitudes, respectively. However, during July the Palmer Peninsula is a "favored" location of cyclonic activity at about 69° S. When summarized by seasons, the data show cyclonic activity to be centered slightly more to the north in summer than in winter with the spring and fall positions being, on the average, farther to the south.

2.2.5 Region V (Weddell Sea)

The percentage frequency of occurrence of cyclones noted in this region is noticeably less throughout the year than in any of the previous regions discussed. The month to month variation in latitudinal locations of the center of cyclonic activity in the region is somewhat more erratic than was the case in the Bellingshausen Sea region, although the seasonal positions reflect essentially the same relative displacement with season; the winter and fall positions are found slightly poleward of the summer position.

2.2.6 Region VI (The Antarctic Continent)

As stated previously, discussion of the percentage frequency of occurrence of low centers over the continent of Antarctica will refer primarily to monthly and seasonal displacement of the 2 percent isopleth.

With the exception of Marie Byrd Land and the Ross Ice Shelf--Ross Sea areas, the 2 percent isopleth is displaced farthest into the continent during fall. Its location in spring is a few degrees to the north, with the winter and summer positions occurring between these two extremes. Thus, cyclones penetrate deeper into the continent during fall than during the rest of the year, on the average.

The situation in the Marie Byrd Land--Ross Sea area is somewhat different. It is in this area that cyclones apparently make their deepest penetration into the interior of Antarctica. A ridge of maximum percentage frequency of occurrence of low centers extends from the eastern part of the Ross Sea to Byrd Station during spring. The general shape of the 2 percent isopleth on the chart for summer indicates that this ridge is displaced to the west during this season and extends from Little America to approximately 85° S. latitude. The ridge of maximum percentage frequency of occurrence tends to shift slightly to the west with the seasons, beginning with its easternmost position during spring and culminating in winter when it is located over the center of the Ross Ice Shelf. Coupled with this longitudinal shift of cyclone activity in the Marie Byrd--Ross Sea area there is also a latitudinal shift between the 6 month periods comprising the seasons of spring-summer and fall-winter, with the former being about 5° to the south of the latter.

Concerning the frequency of occurrence of cyclonic activity over the rest of the continent, the data suggest that on the average cyclones penetrate to the interior at least occasionally during all seasons, with the seasonal and monthly variability for a given location of somewhat smaller magnitude than is true for the other regions discussed in this report.

The data used in this study could lead to conclusions concerning the spatial and temporal variation in frequency of occurrence of low centers over the more elevated areas of Antarctica; however, various factors--such as the tremendous distances between stations, the extreme altitude of the terrain, and conflicting philosophies of analysis upon which the synoptic charts used in this investigation were based--limit the validity of such conclusions at this time.

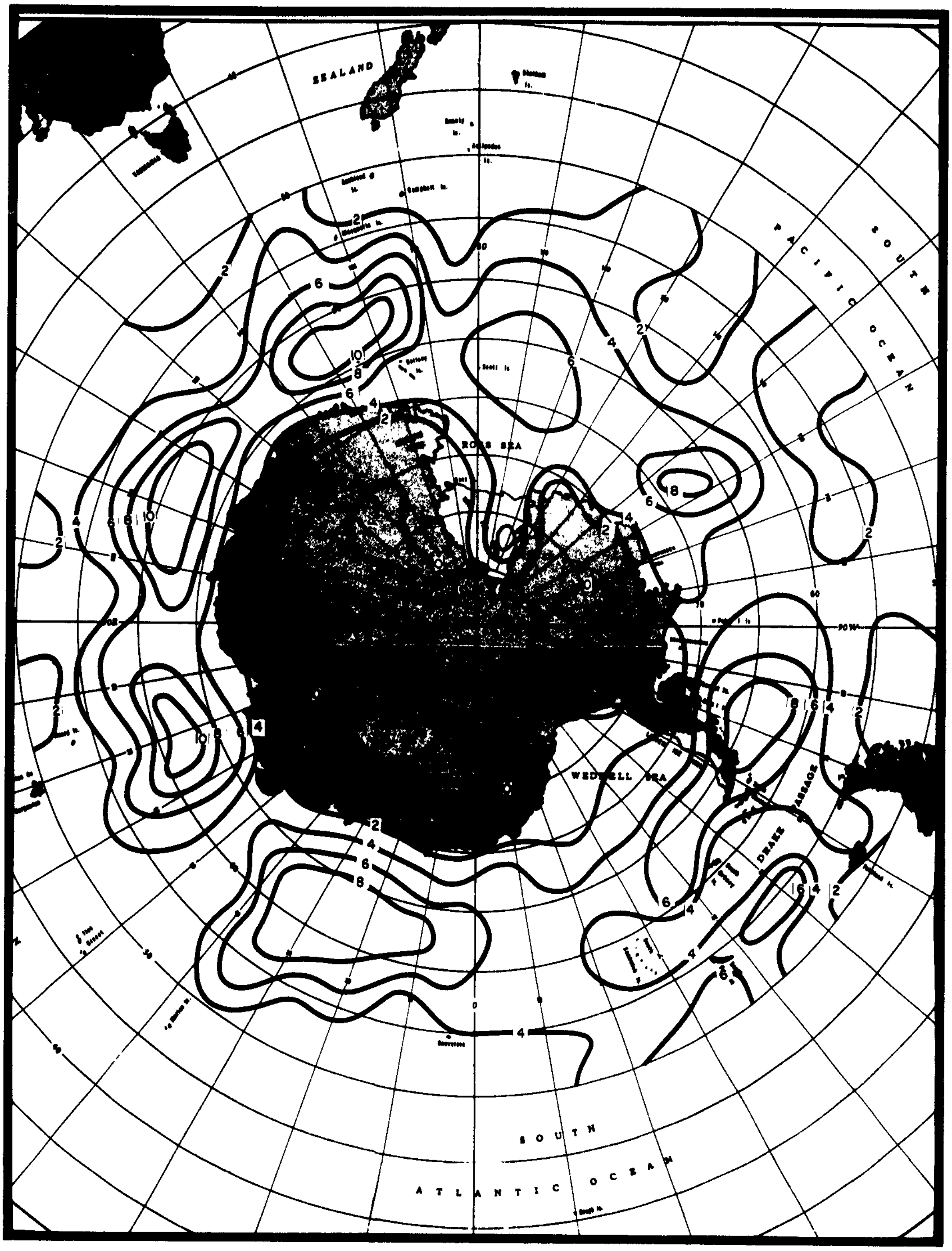


Figure 2.4. Average Percentage Frequency of Occurrence of Low Centers for January.

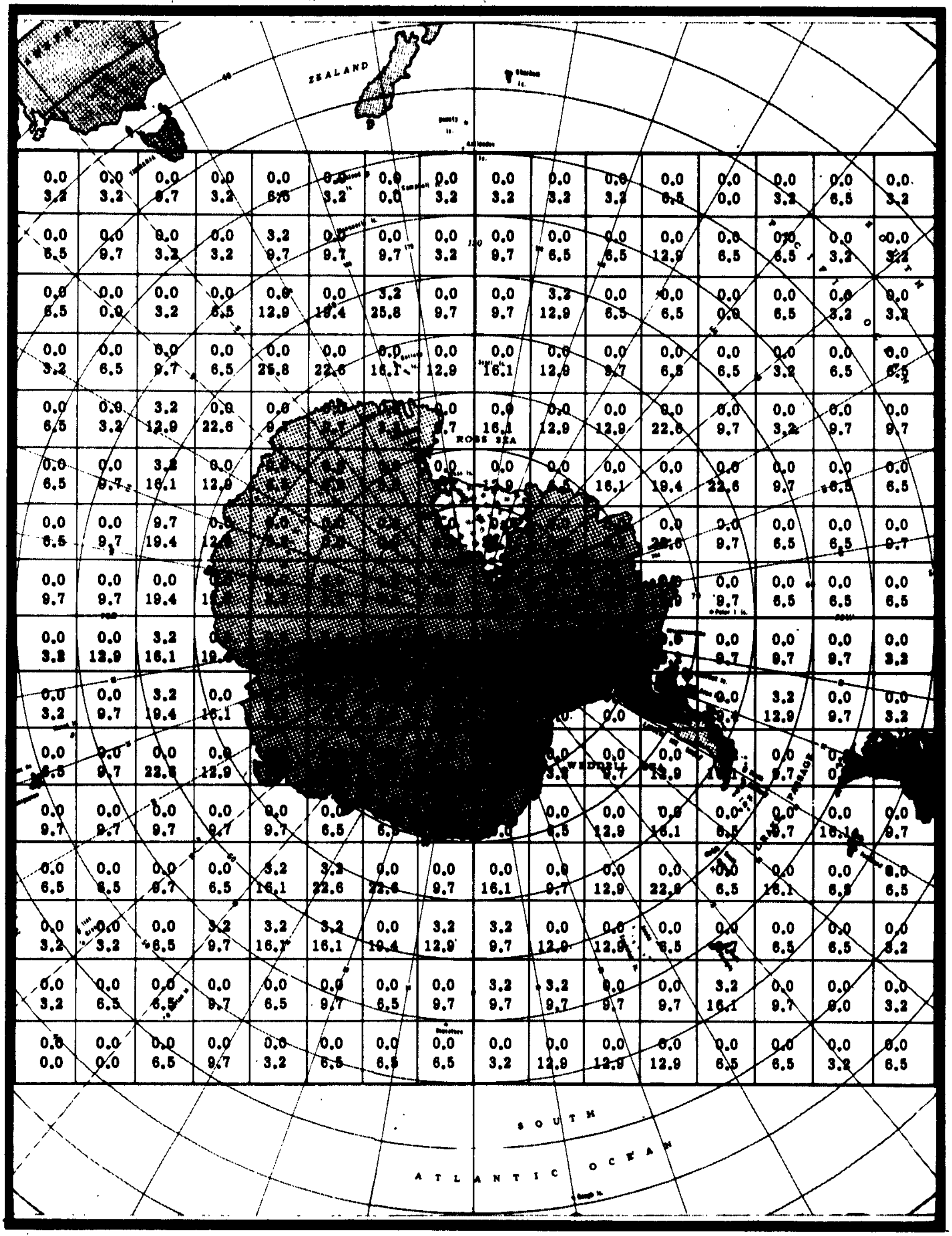


Figure 2.5. Range of Average Monthly Values of Percentage Frequency of Occurrence of Low Centers for January.

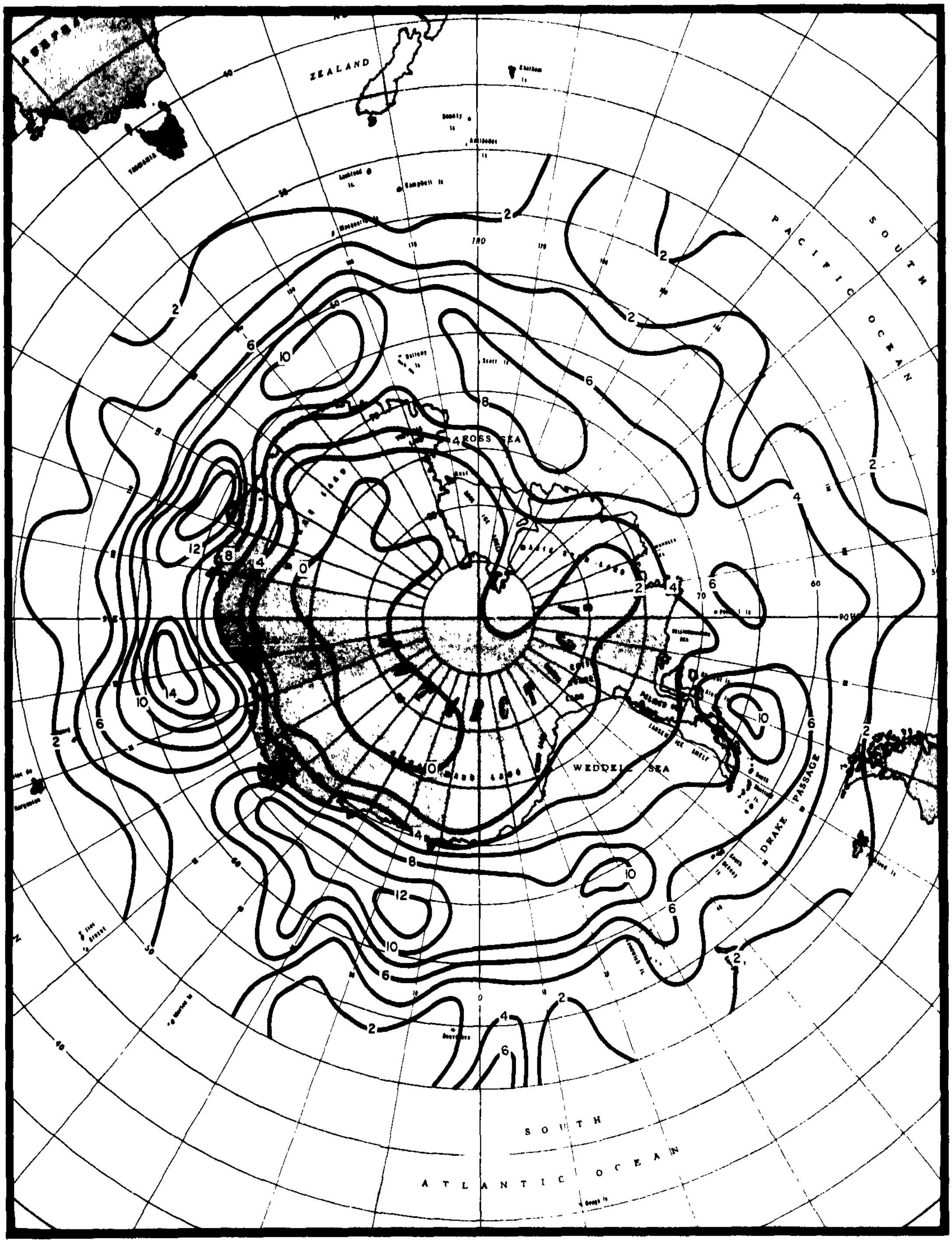


Figure 2.6. Average Percentage Frequency of Occurrence of Low Centers for February.

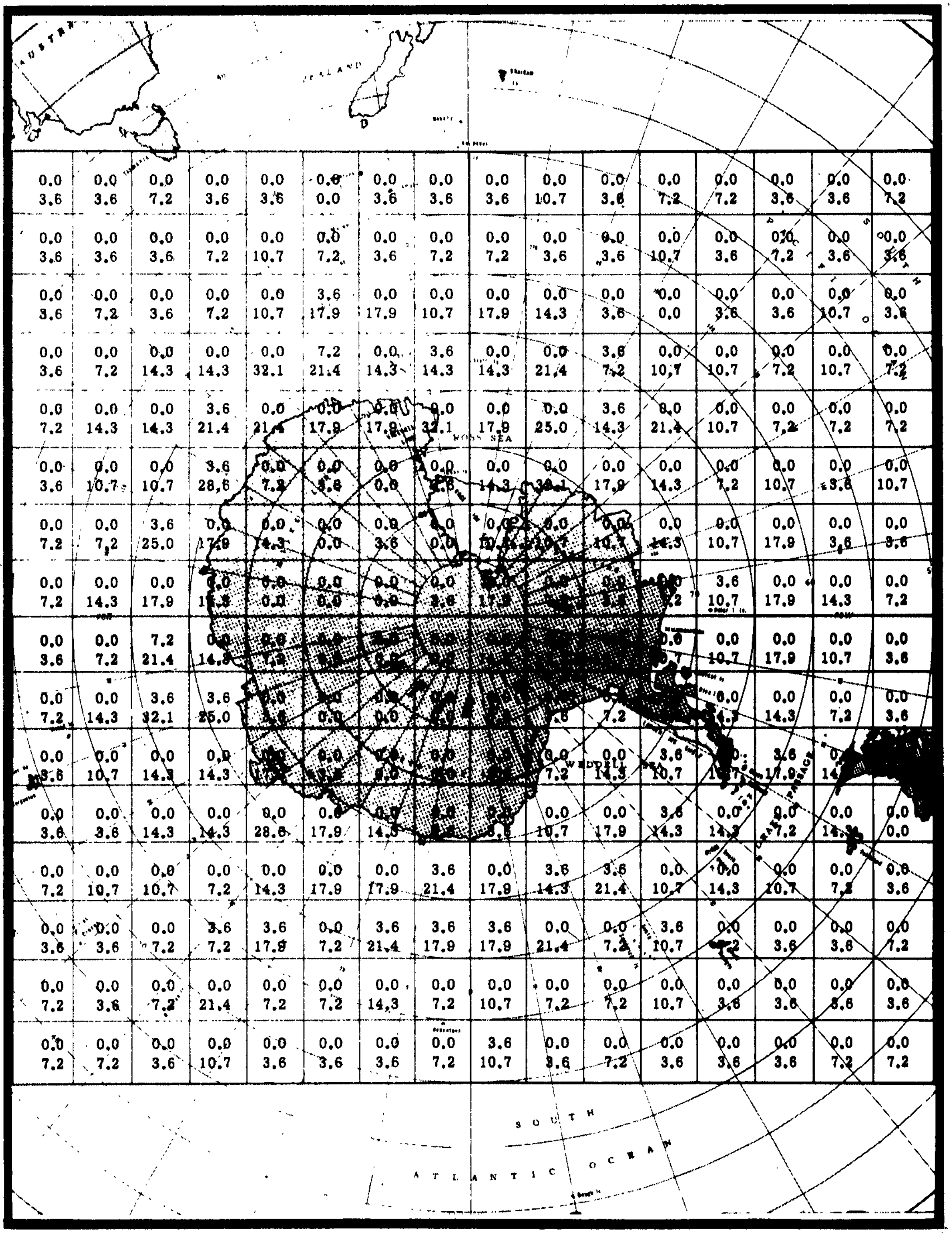


Figure 2.7. Range of Average Monthly Values of Percentage Frequency of Occurrence of Low Centers for February.

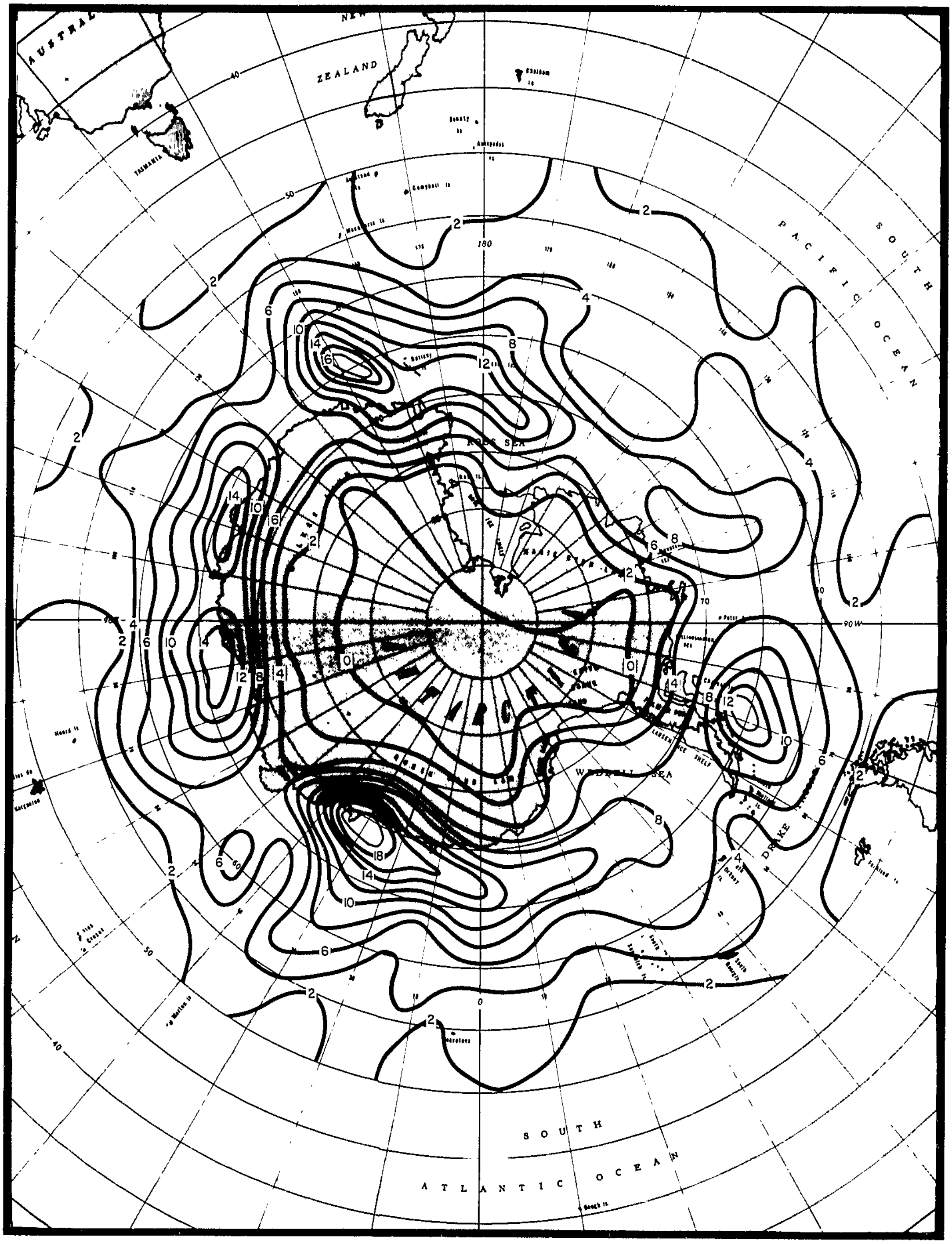


Figure 2.8. Average Percentage Frequency of Occurrence of Low Centers for March.

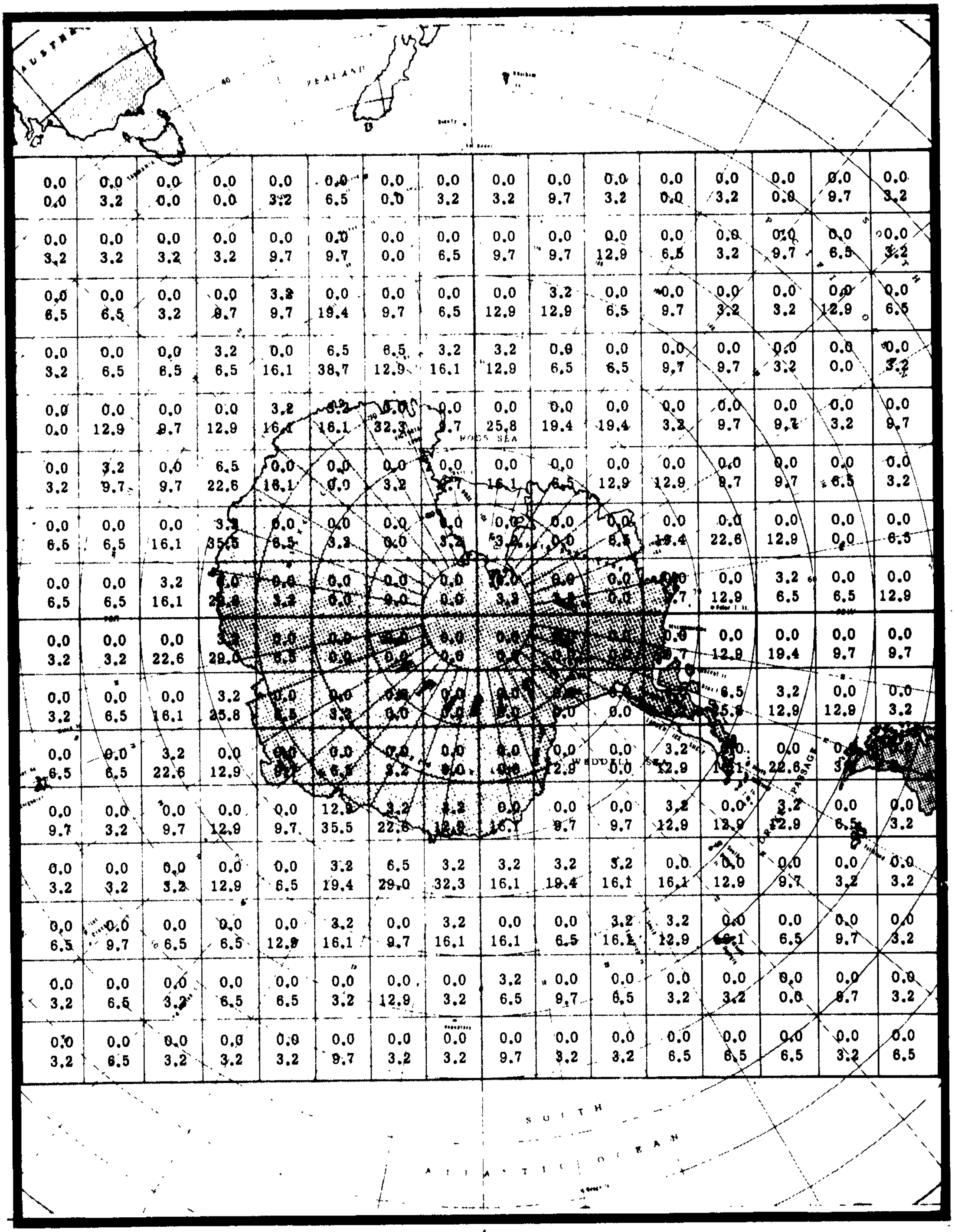


Figure 2.9. Range of Average Monthly Values of Percentage Frequency of Occurrence of Low Centers for March.

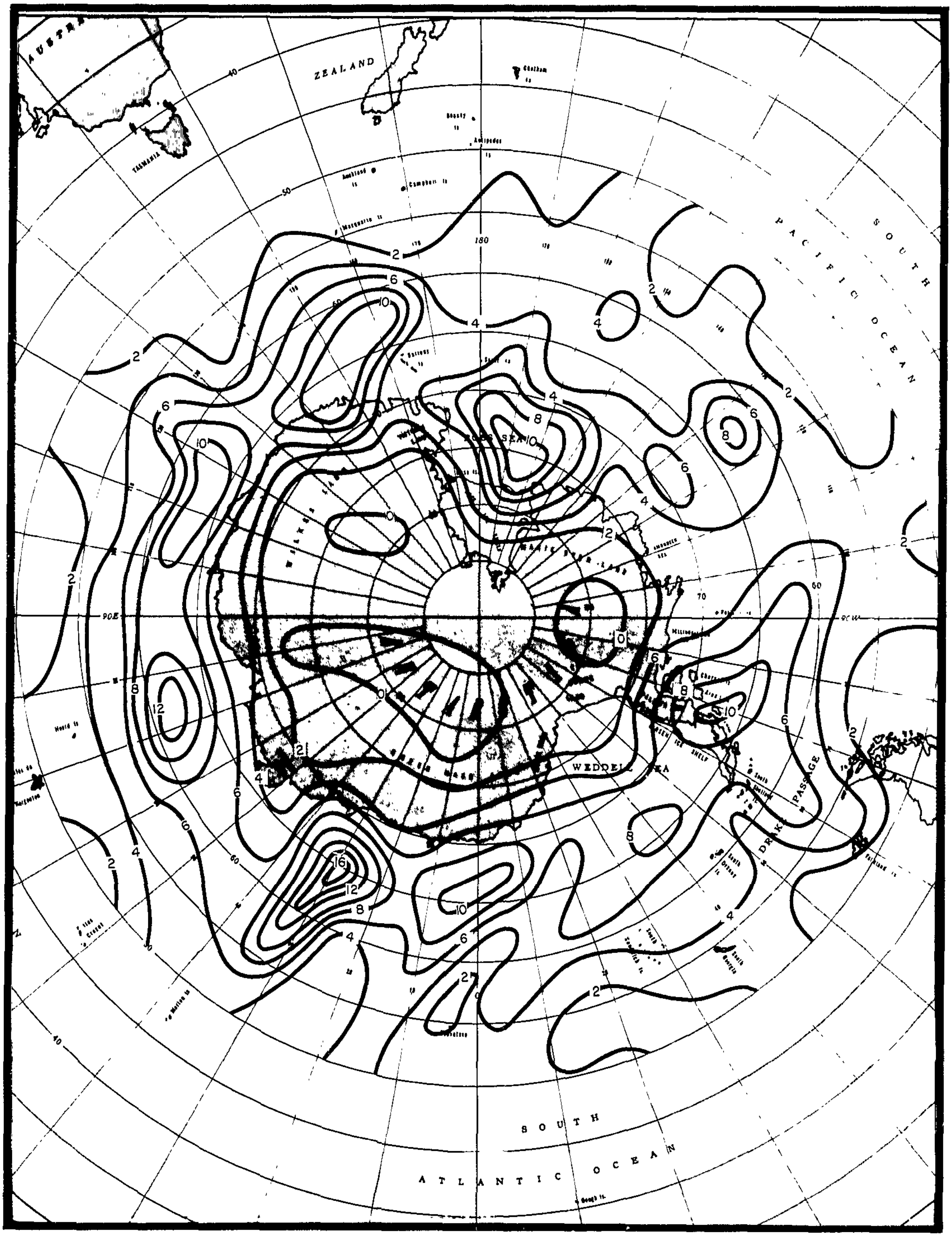


Figure 2.10. Average Percentage Frequency of Occurrence of Low Centers for April.

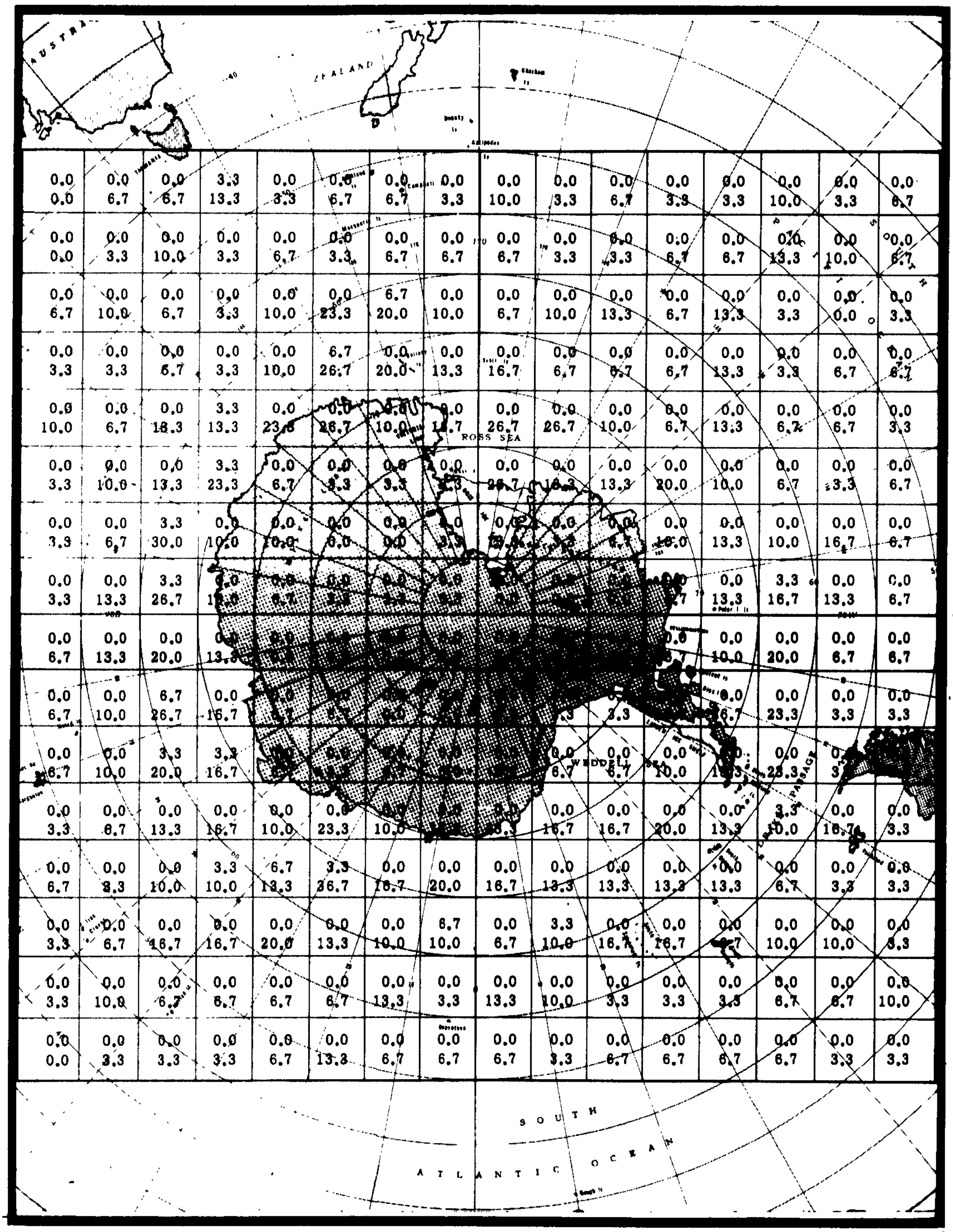


Figure 2.11. Range of Average Monthly Values of Percentage Frequency of Occurrence of Low Centers for April.

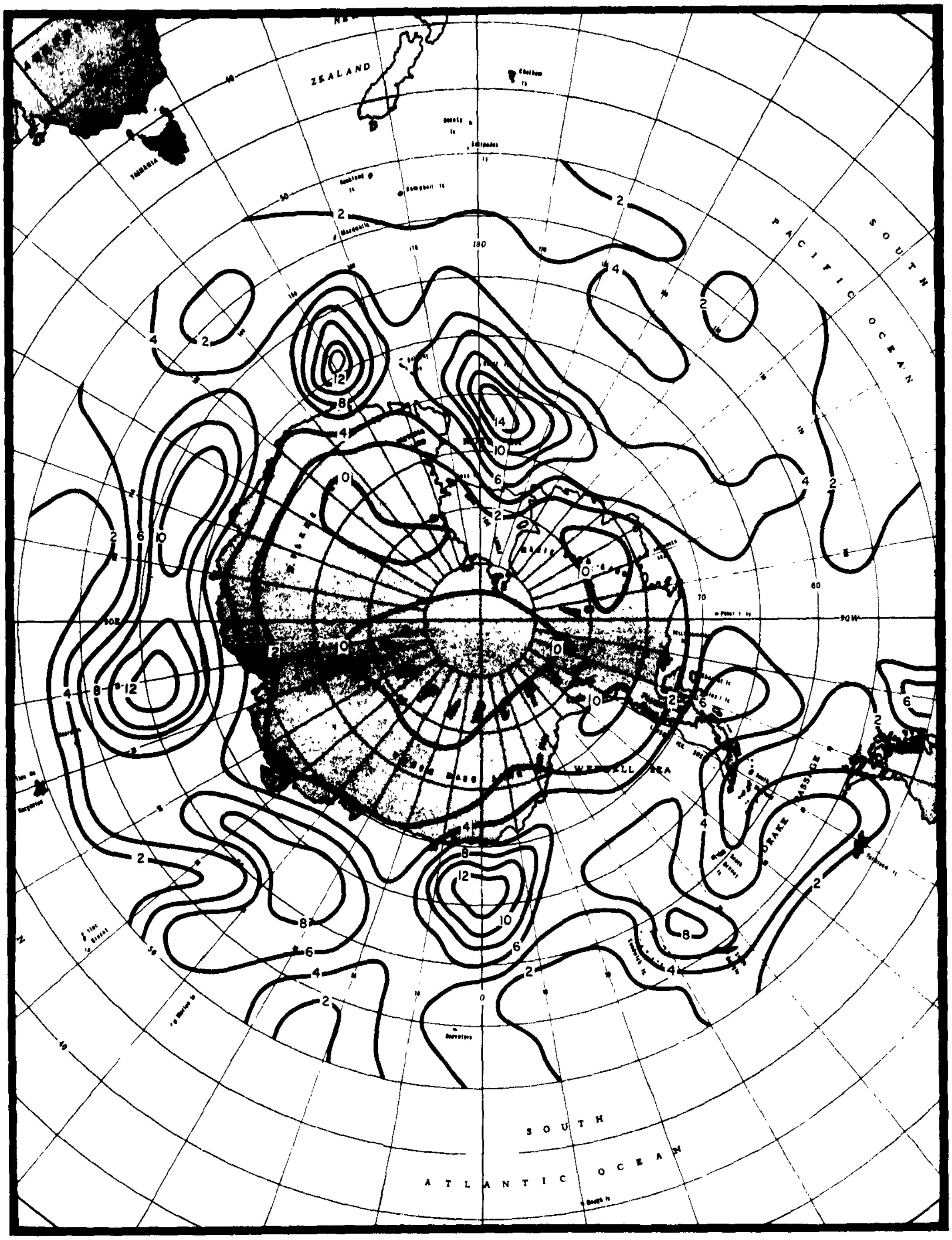


Figure 2.12. Average Percentage Frequency of Occurrence of Low Centers for May.

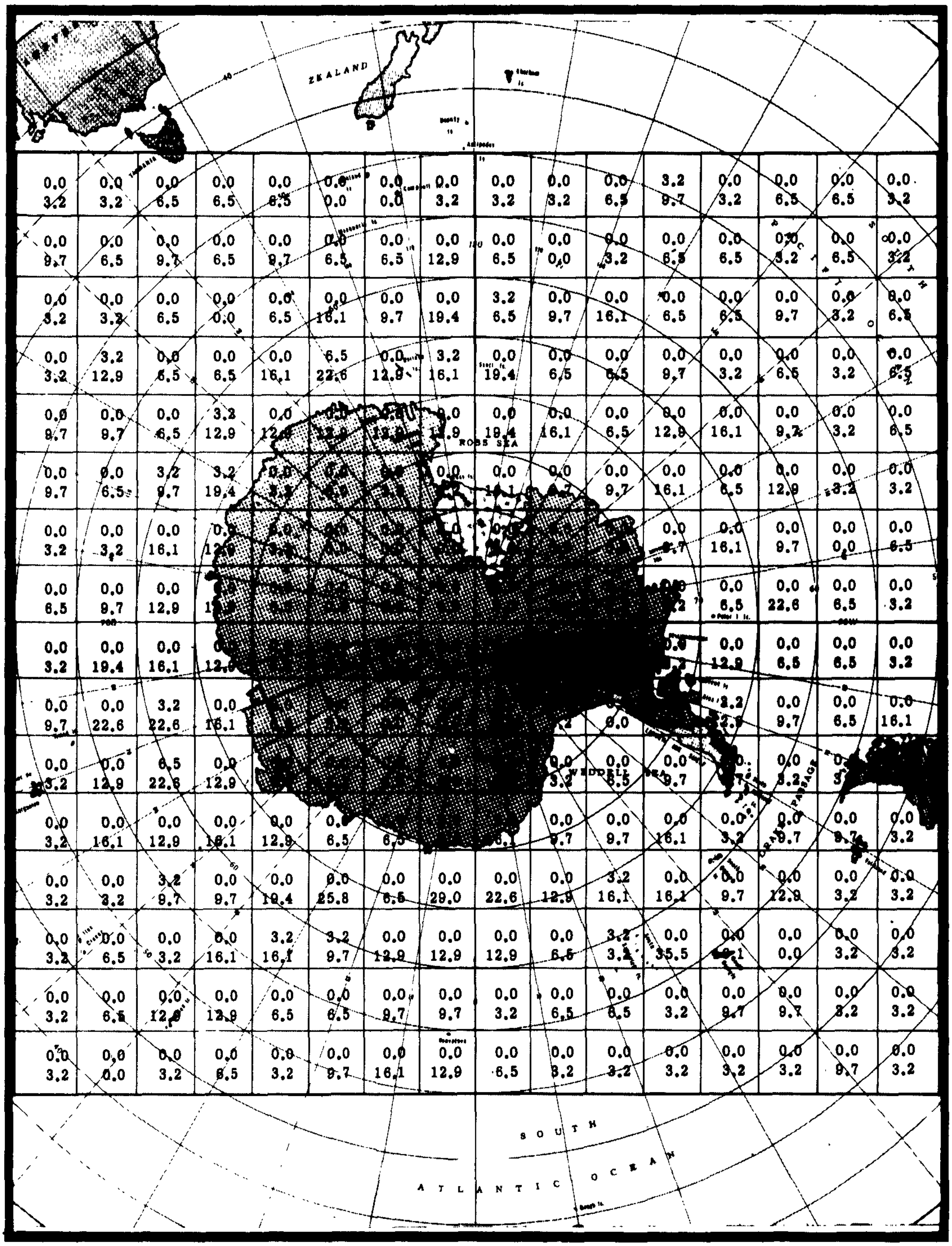


Figure 2.13. Range of Average Monthly Values of Percentage Frequency of Occurrence of Low Centers for May.

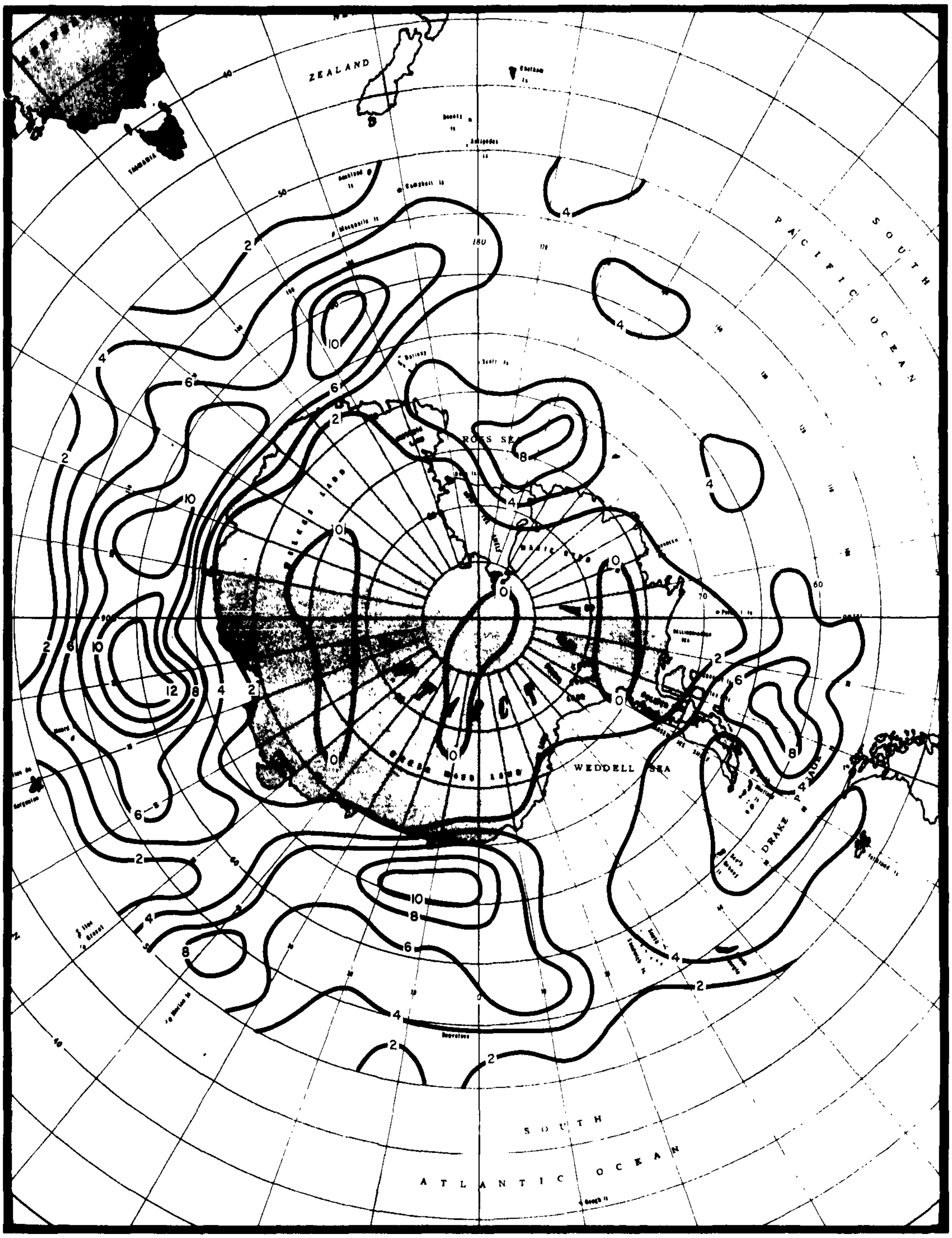


Figure 2.14. Average Percentage Frequency of Occurrence of Low Centers for June.

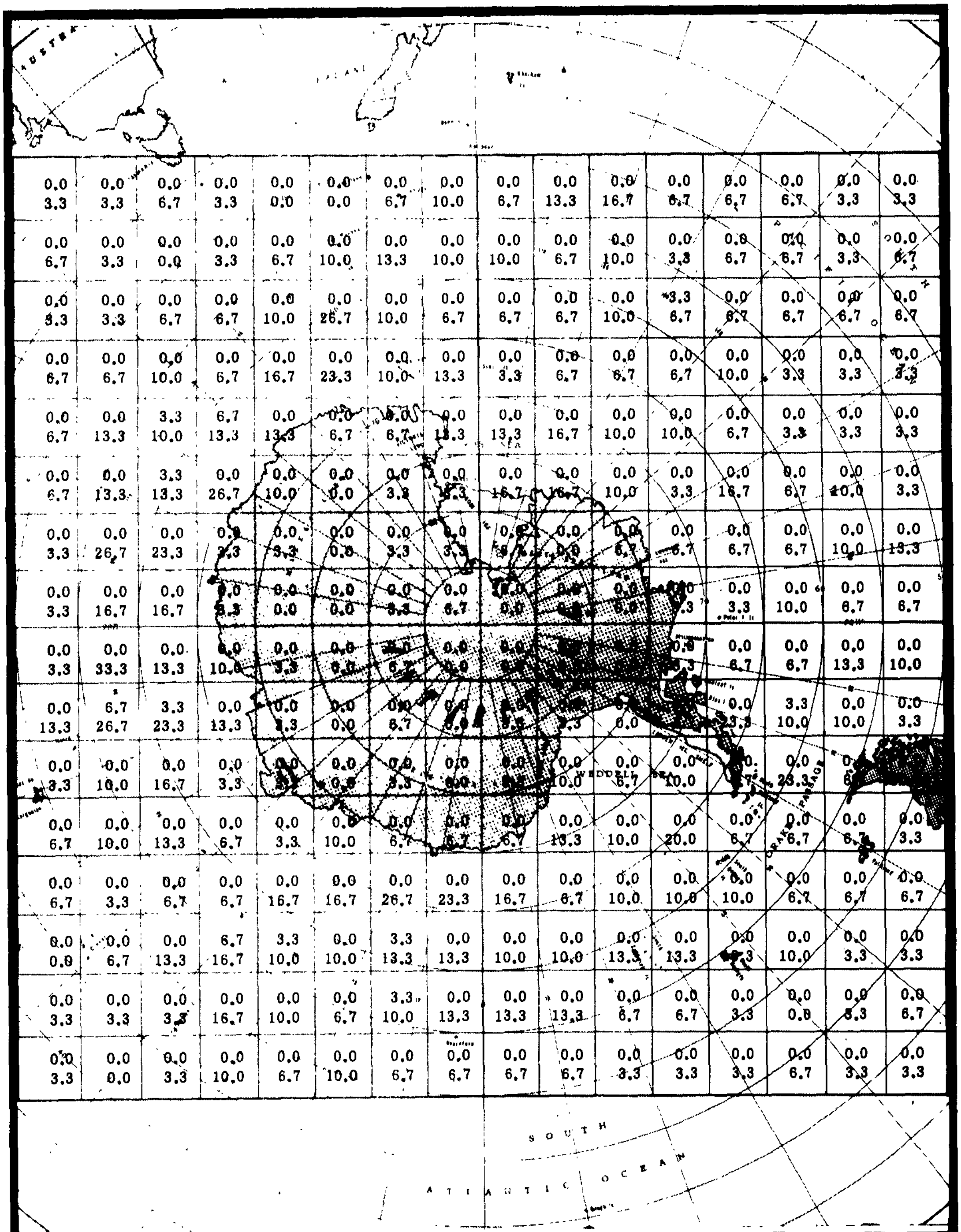


Figure 2.15. Range of Average Monthly Values of Percentage Frequency of Occurrence of Low Centers for June.

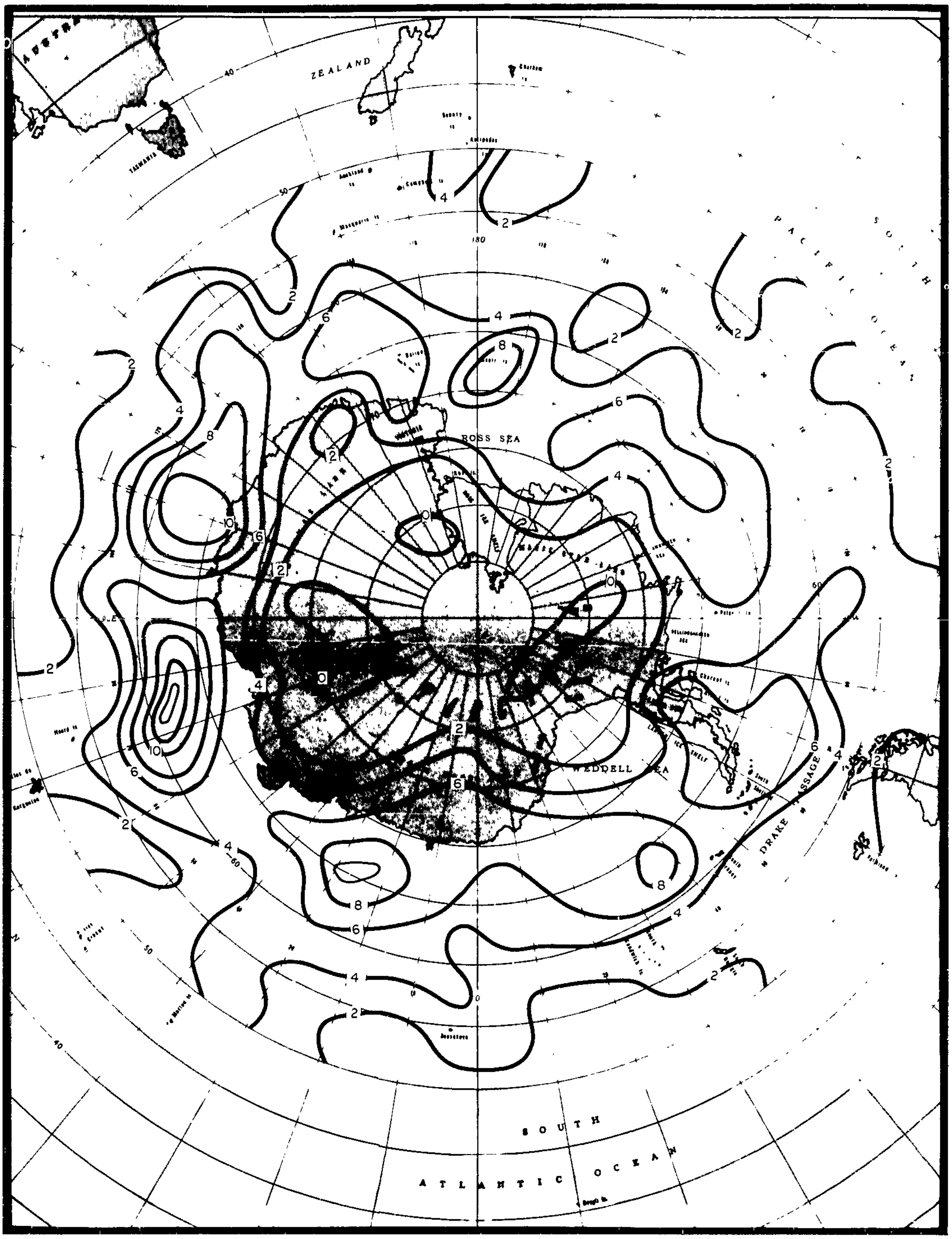


Figure 2.16. Average Percentage Frequency of Occurrence of Low Centers for July.

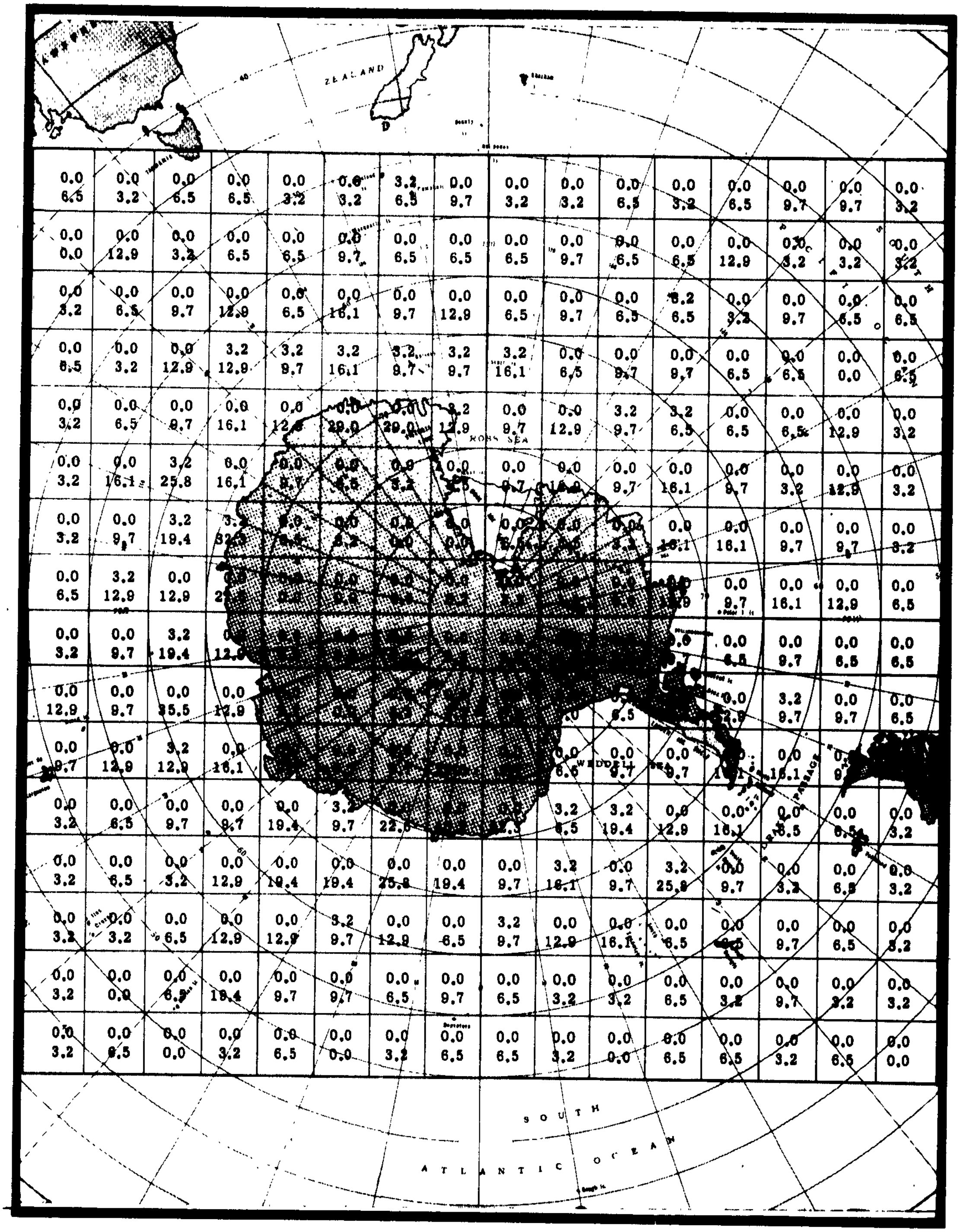


Figure 2.17. Range of Average Monthly Values of Percentage Frequency of Occurrence of Low Centers for July.

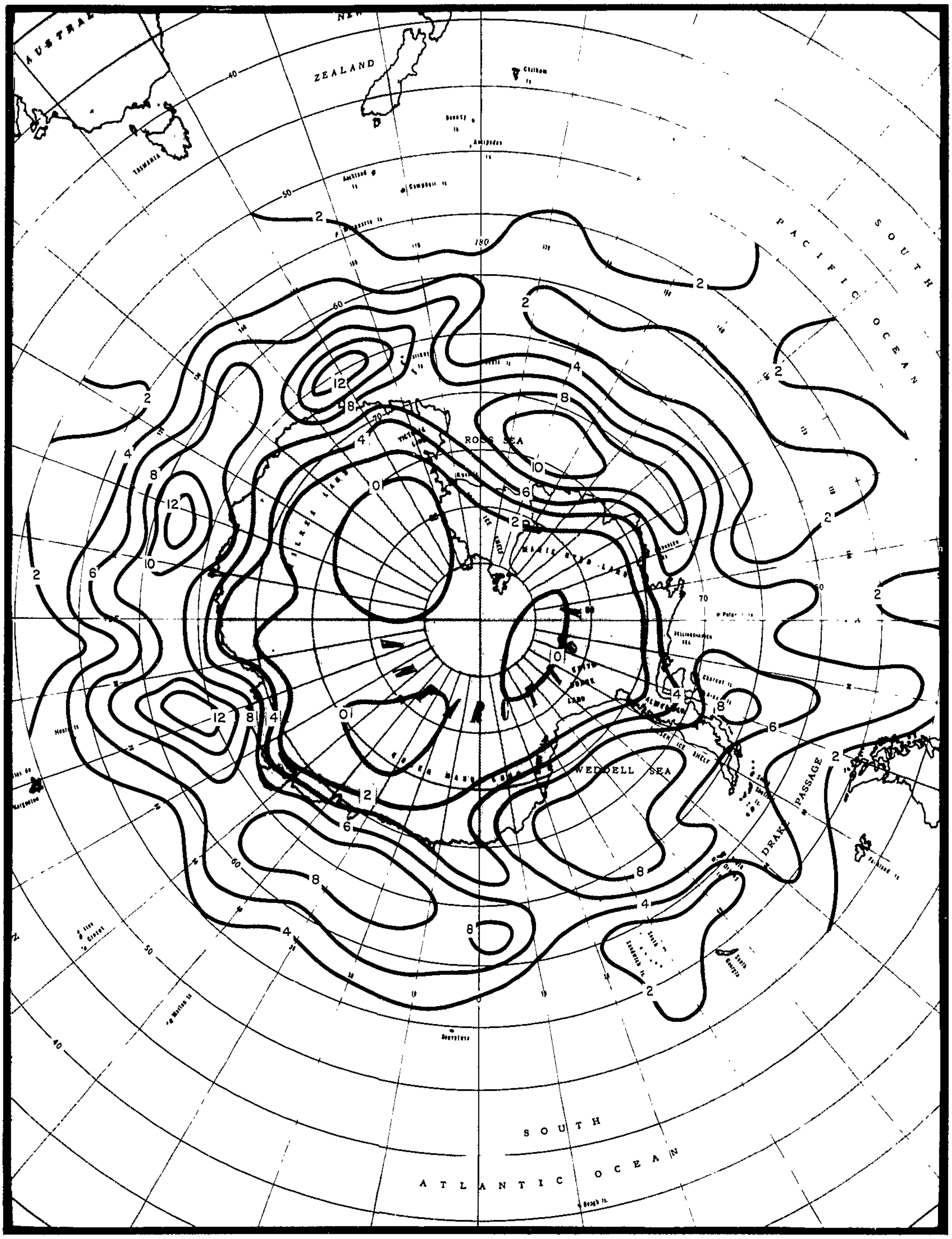


Figure 2.18. Average Percentage Frequency of Occurrence of Low Centers for August.

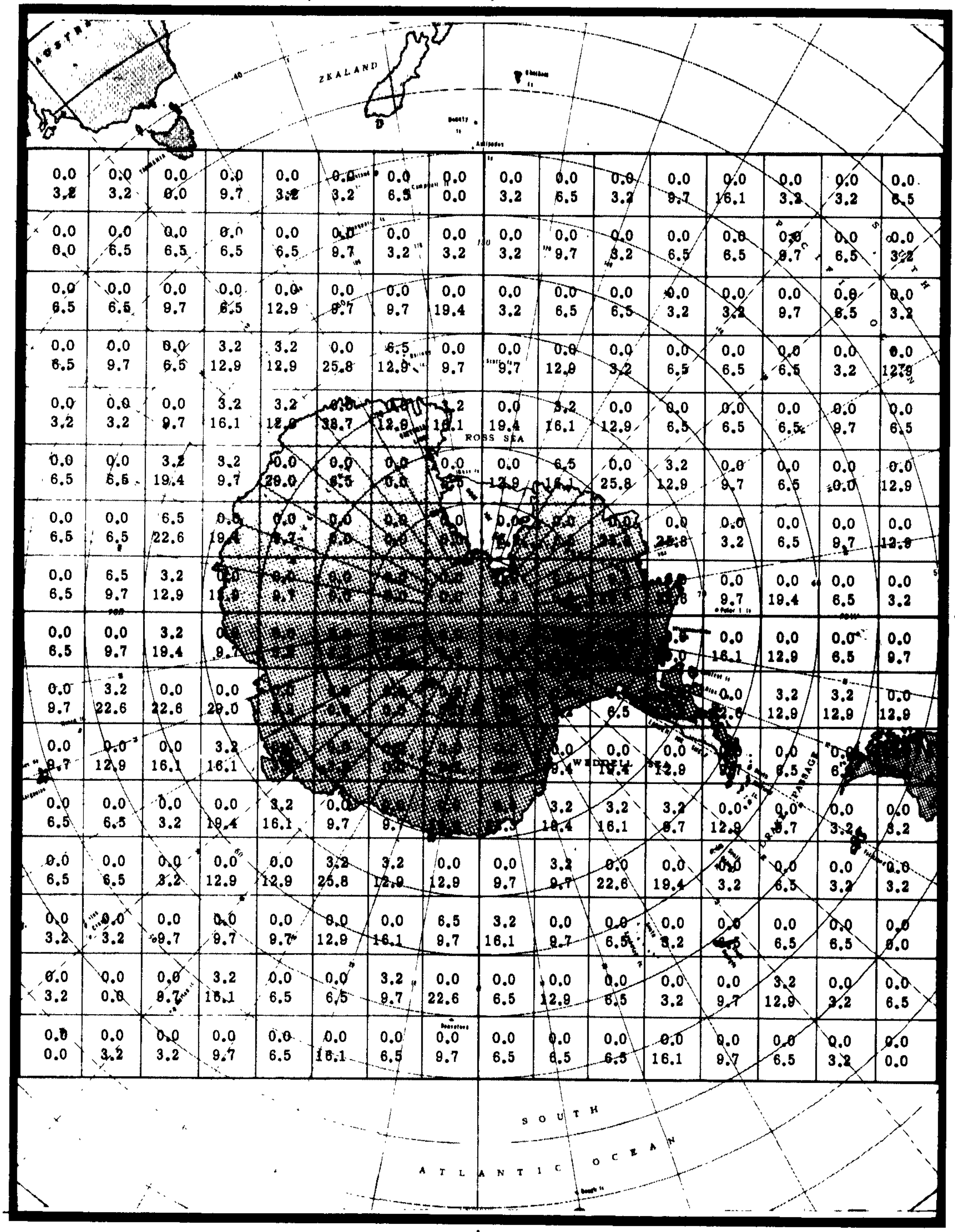


Figure 2.19. Range of Average Monthly Values of Percentage Frequency of Occurrence of Low Centers for August.

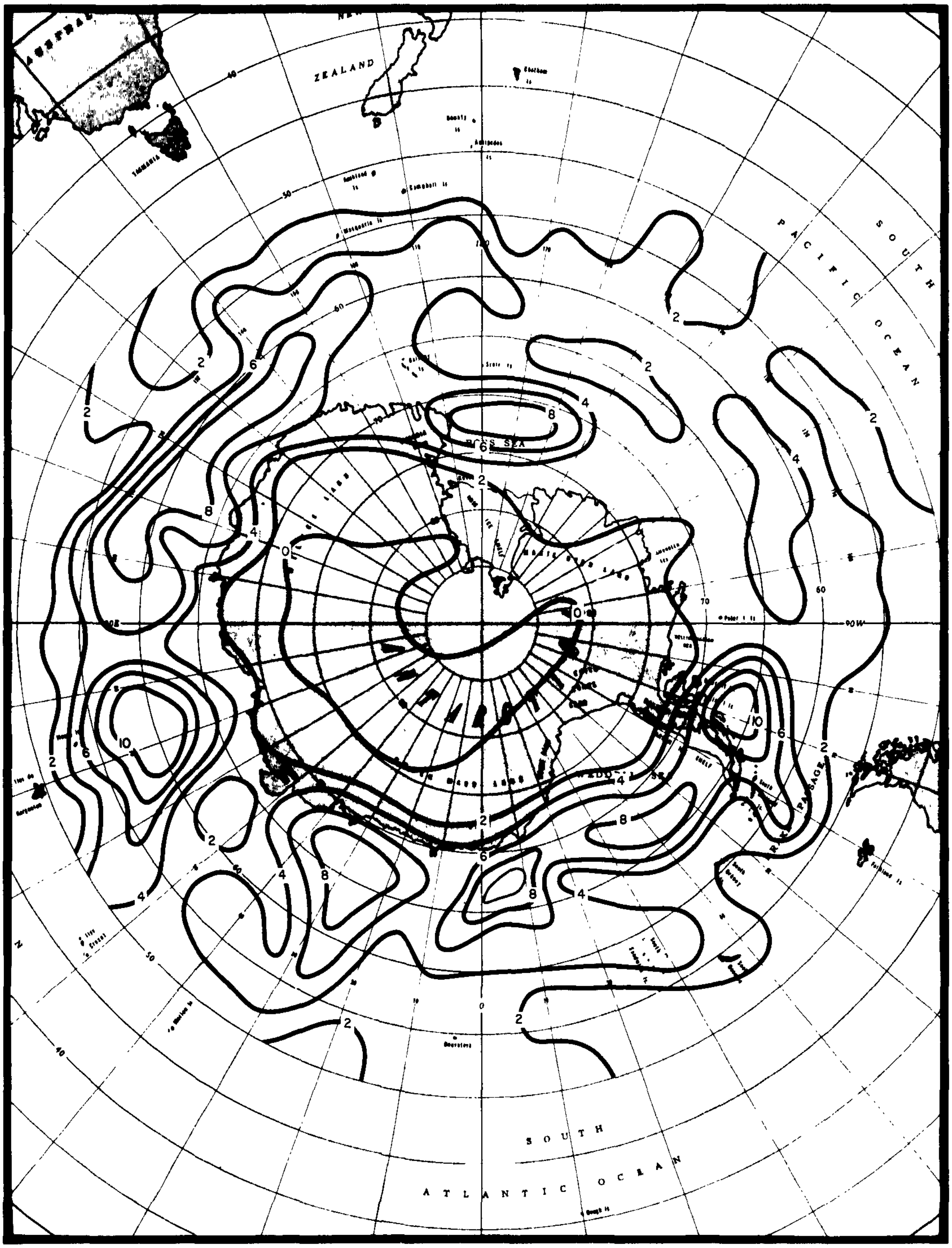


Figure 2.20. Average Percentage Frequency of Occurrence of Low Centers for September.

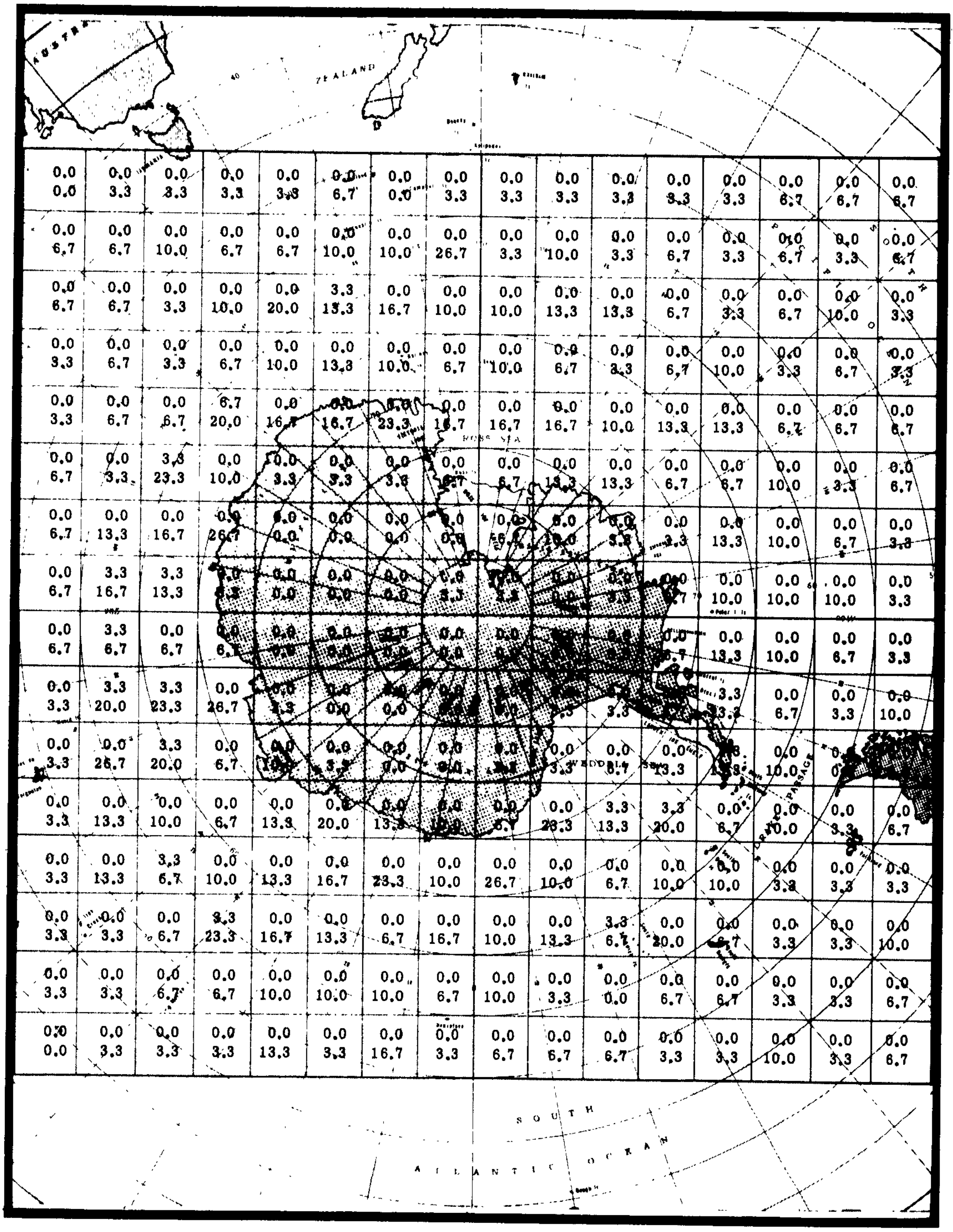


Figure 2.21. Range of Average Monthly Values of Percentage Frequency of Occurrence of Low Centers for September.

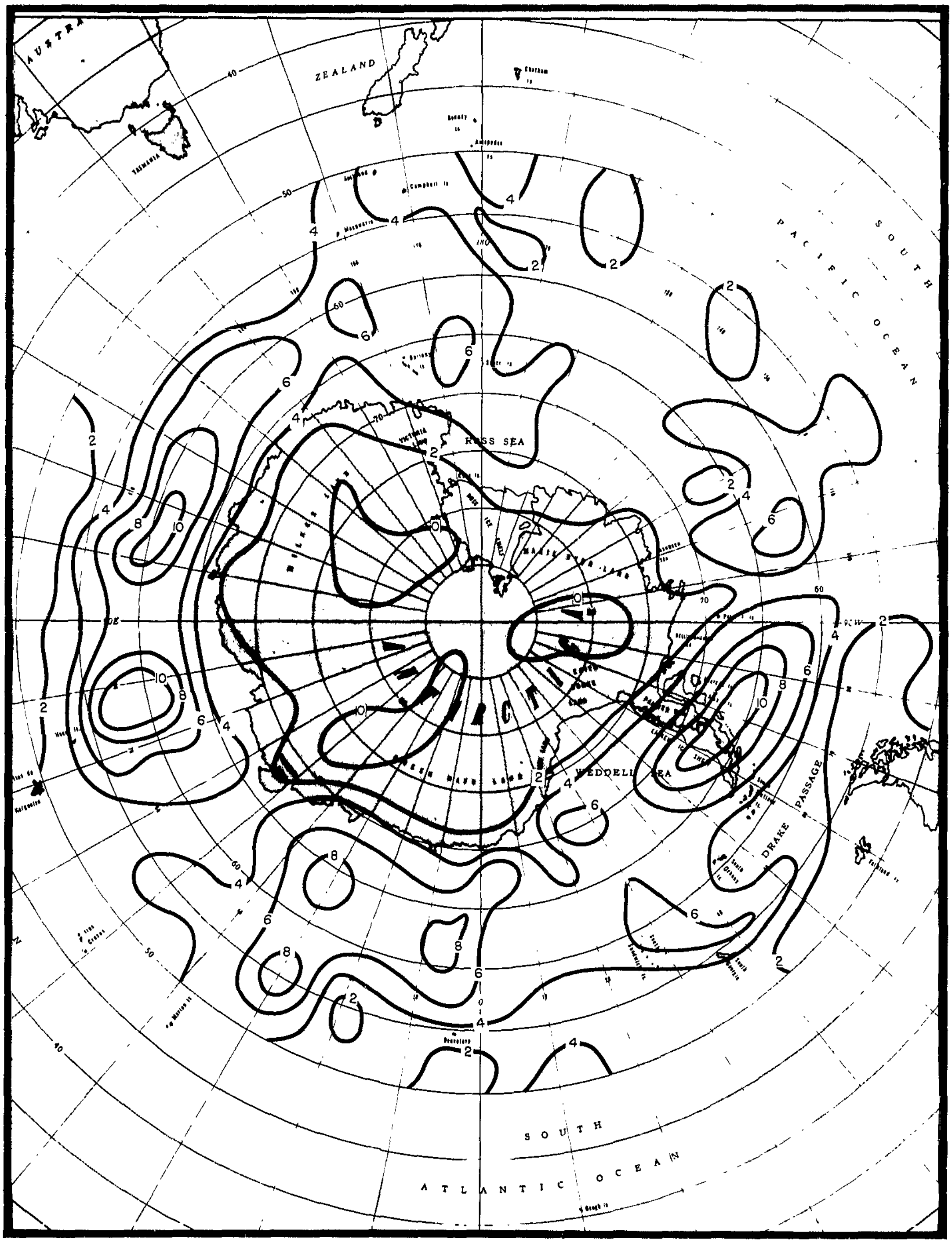
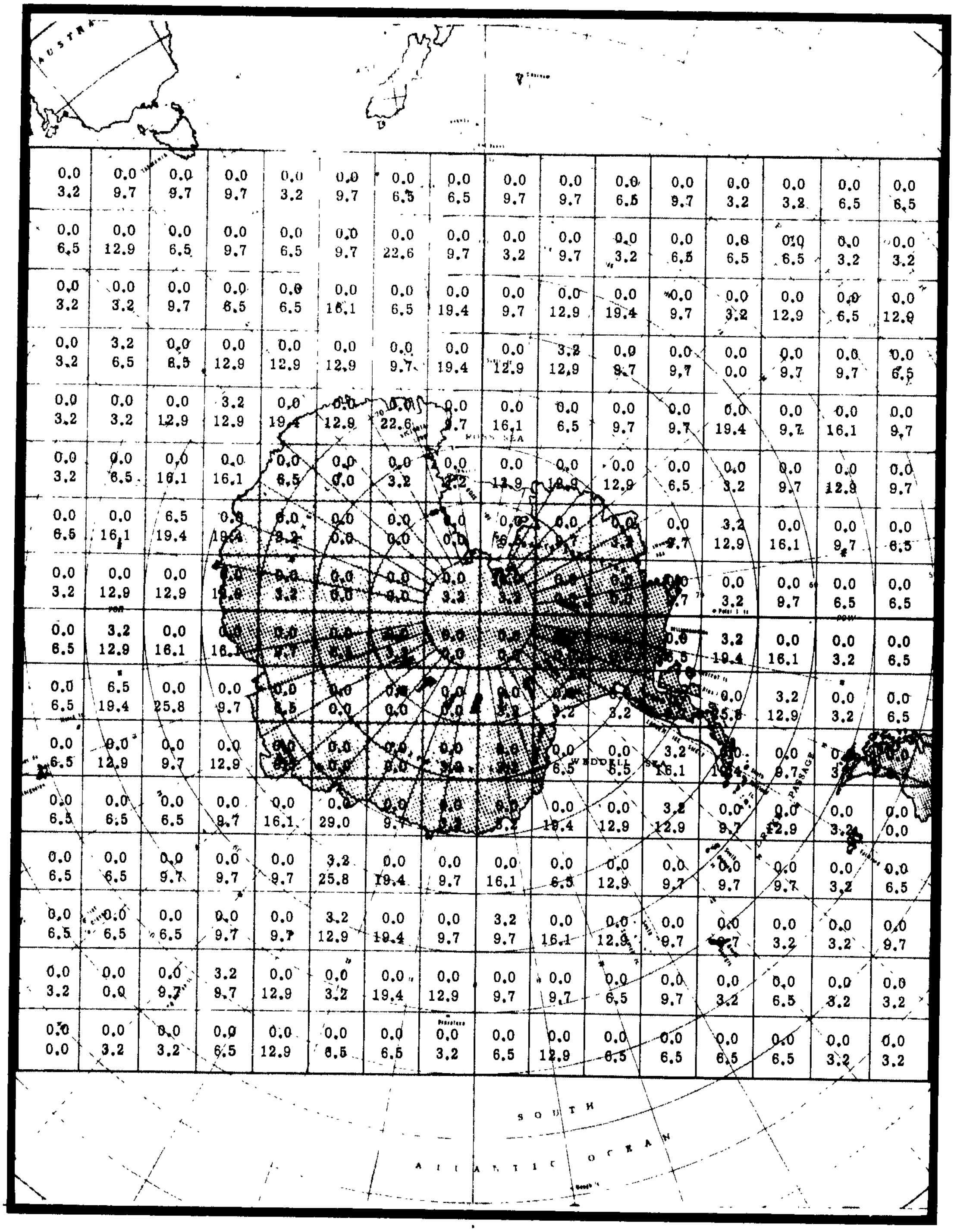


Figure 2.22. Average Percentage Frequency of Occurrence of Low Centers for October.



0.0 3.2	0.0 9.7	0.0 9.7	0.0 9.7	0.0 3.2	0.0 9.7	0.0 6.5	0.0 6.5	0.0 9.7	0.0 9.7	0.0 6.5	0.0 9.7	0.0 3.2	0.0 3.2	0.0 6.5	0.0 6.5
0.0 6.5	0.0 12.9	0.0 6.5	0.0 9.7	0.0 6.5	0.0 9.7	0.0 22.6	0.0 9.7	0.0 3.2	0.0 9.7	0.0 3.2	0.0 6.5	0.0 6.5	0.0 6.5	0.0 3.2	0.0 3.2
0.0 3.2	0.0 3.2	0.0 9.7	0.0 6.5	0.0 6.5	0.0 16.1	0.0 6.5	0.0 19.4	0.0 9.7	0.0 12.9	0.0 19.4	0.0 9.7	0.0 3.2	0.0 12.9	0.0 6.5	0.0 12.9
0.0 3.2	3.2 6.5	0.0 6.5	0.0 12.9	0.0 12.9	0.0 12.9	0.0 9.7	0.0 19.4	0.0 12.9	3.2 12.9	0.0 9.7	0.0 9.7	0.0 0.0	0.0 9.7	0.0 9.7	0.0 6.5
0.0 3.2	0.0 3.2	0.0 12.9	3.2 12.9	0.0 19.4	0.0 12.9	0.0 22.6	0.0 9.7	0.0 16.1	0.0 6.5	0.0 9.7	0.0 9.7	0.0 19.4	0.0 9.7	0.0 16.1	0.0 9.7
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0.0 0.0	0.0 3.2	0.0 3.2	0.0 6.5	0.0 12.9	0.0 6.5	0.0 6.5	0.0 3.2	0.0 6.5	0.0 12.9	0.0 6.5	0.0 6.5	0.0 6.5	0.0 6.5	0.0 3.2	0.0 3.2

Figure 2.23. Range of Average Monthly Values of Percentage Frequency of Occurrence of Low Centers for October.

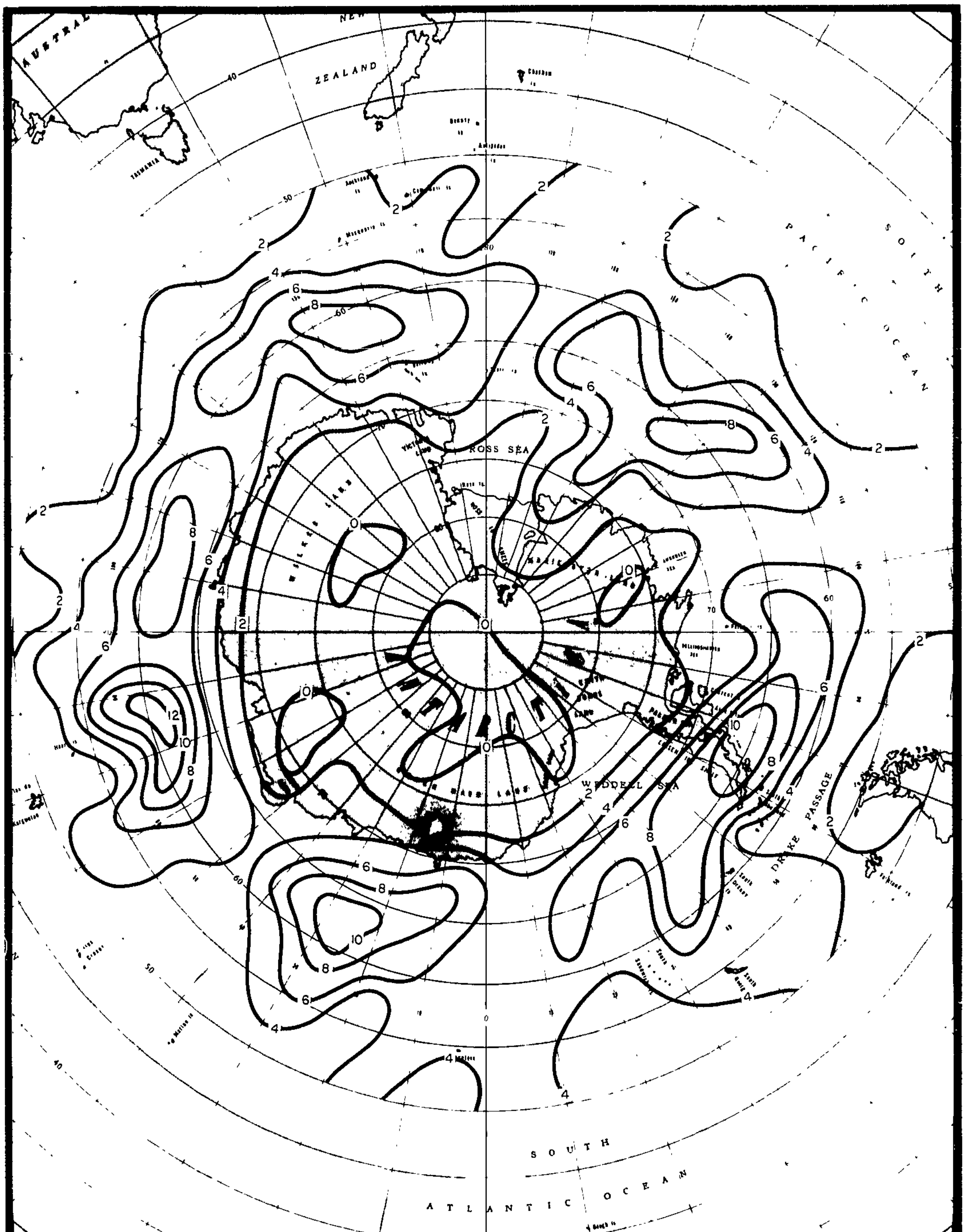

Figure 2.24. Average Percentage Frequency of Occurrence of Low Centers for November.

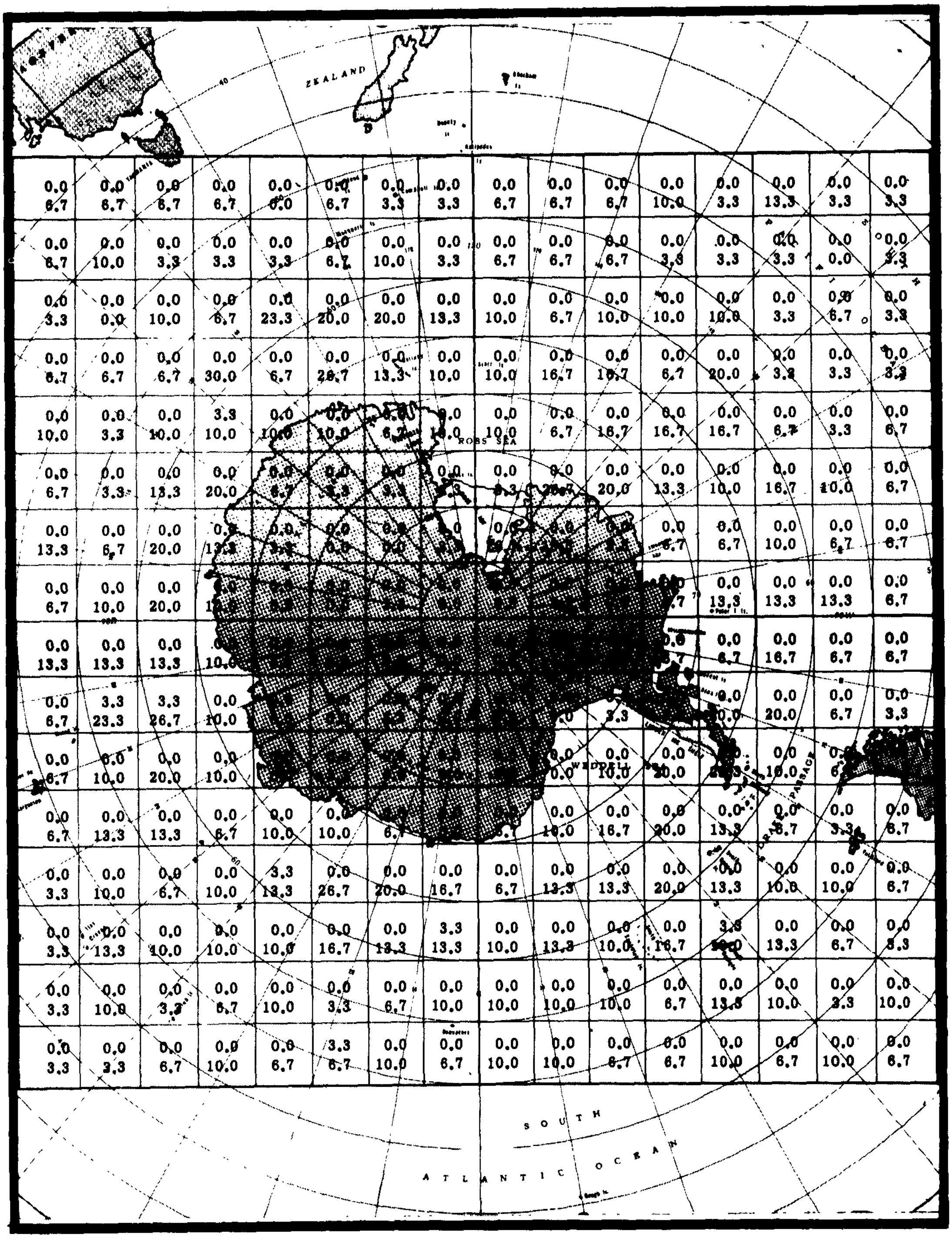

Figure 2.25. Range of Average Monthly Values of Percentage Frequency of Occurrence of Low Centers for November.

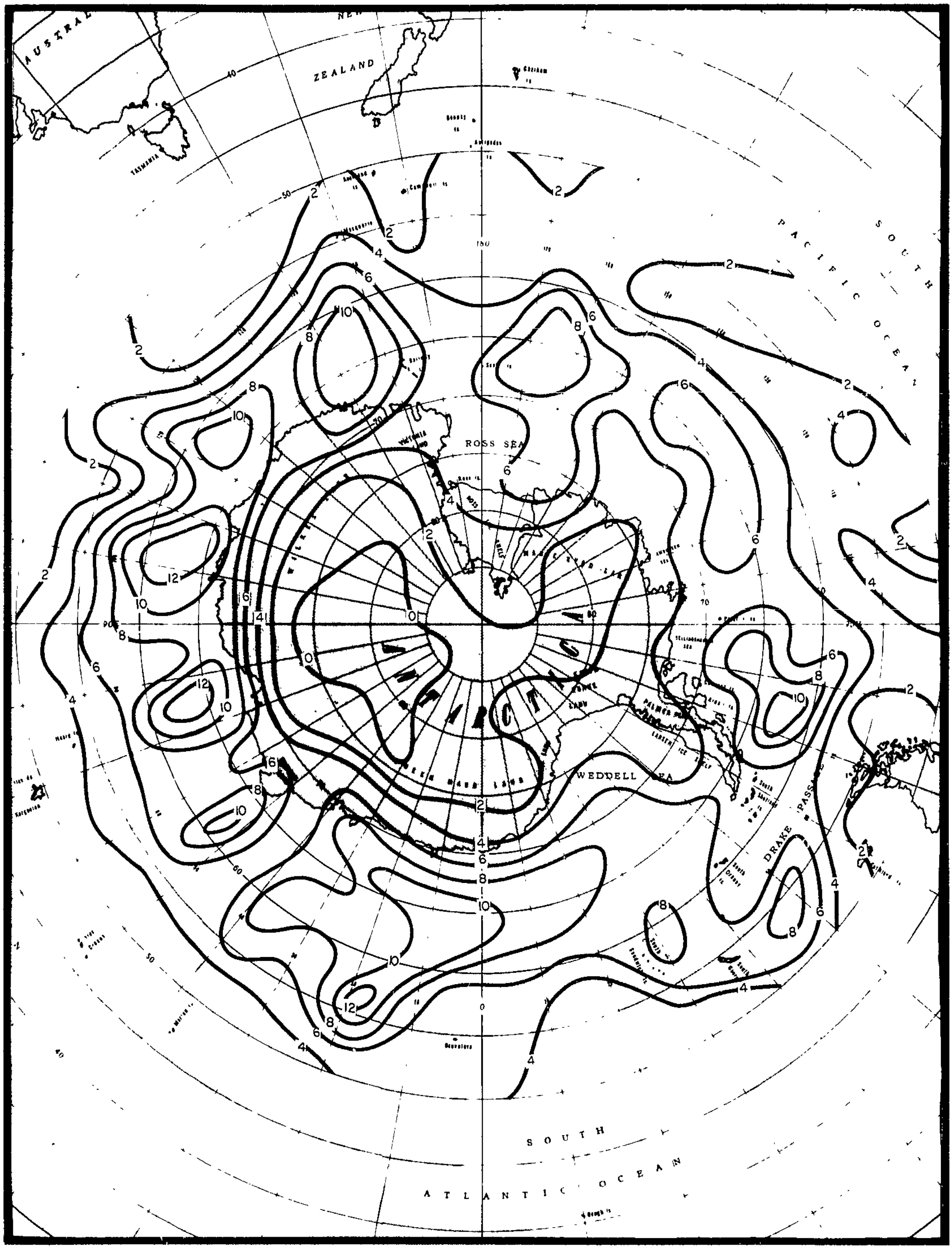

Figure 2.26. Average Percentage Frequency of Occurrence of Low Centers for December.

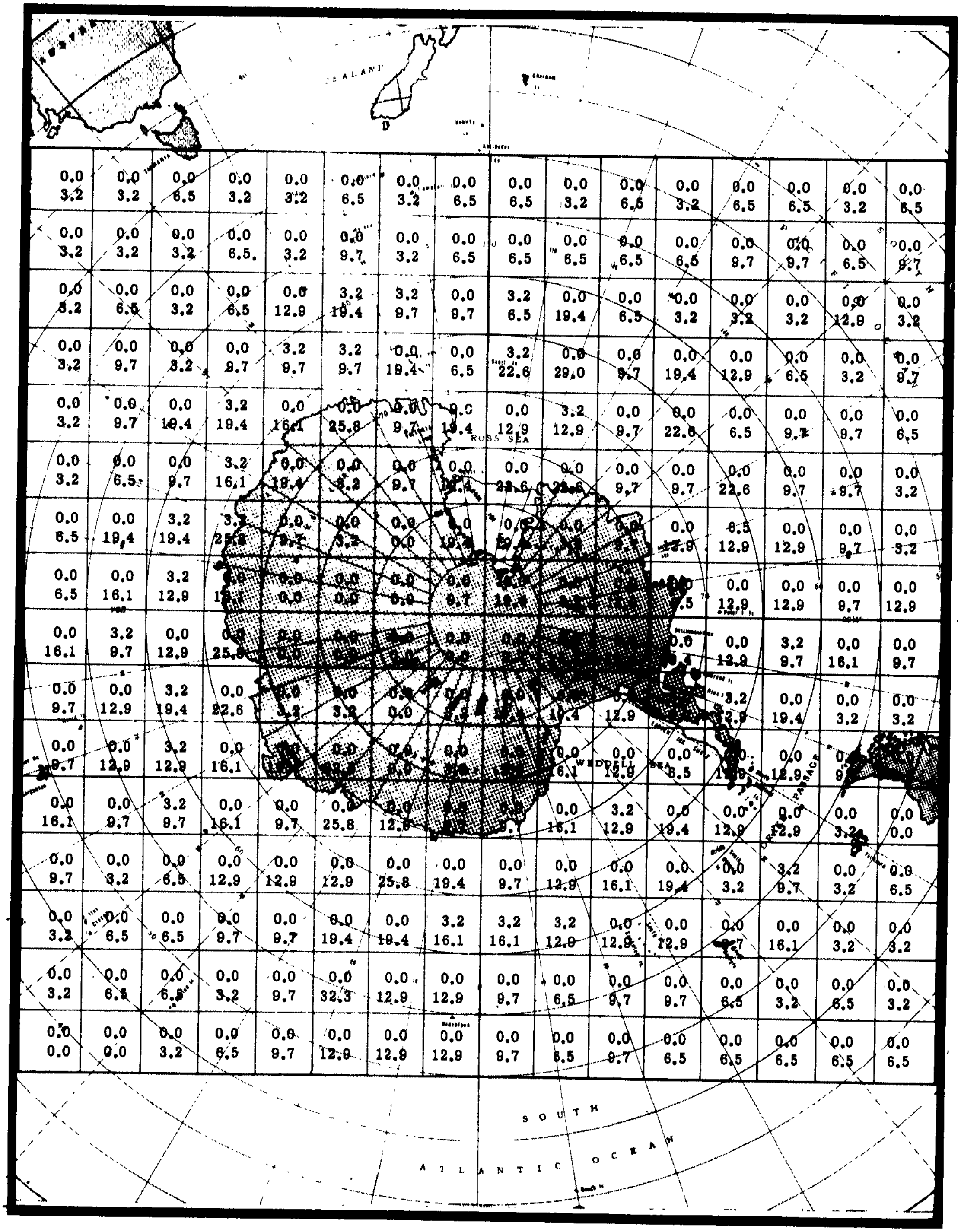

Figure 2.27. Range of Average Monthly Values of Percentage Frequency of Occurrence of Low Centers for December.

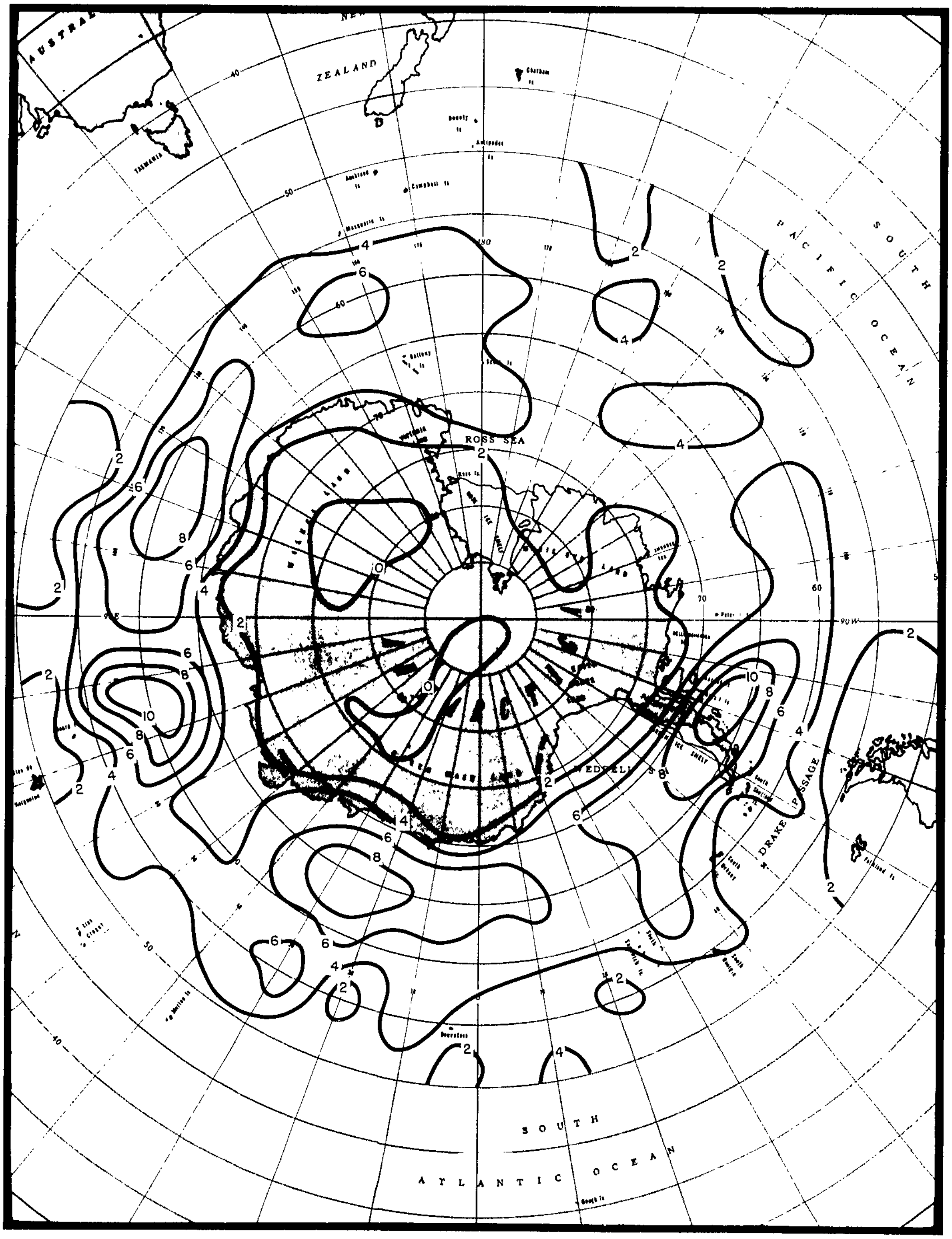

Figure 2.28. Average Percentage Frequency of Occurrence of Low Centers for Spring.

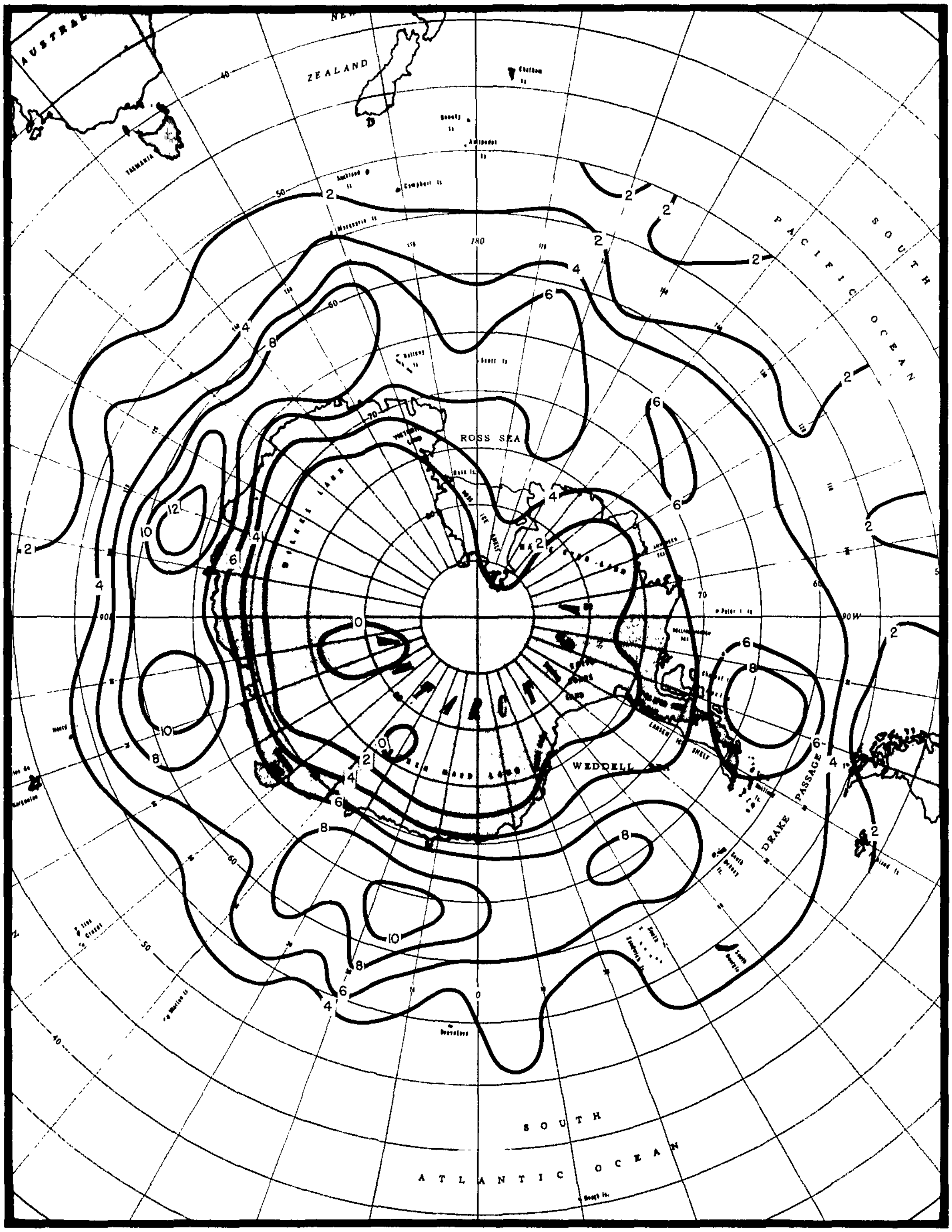

Figure 2.29. Average Percentage Frequency of Occurrence of Low Centers for Summer.

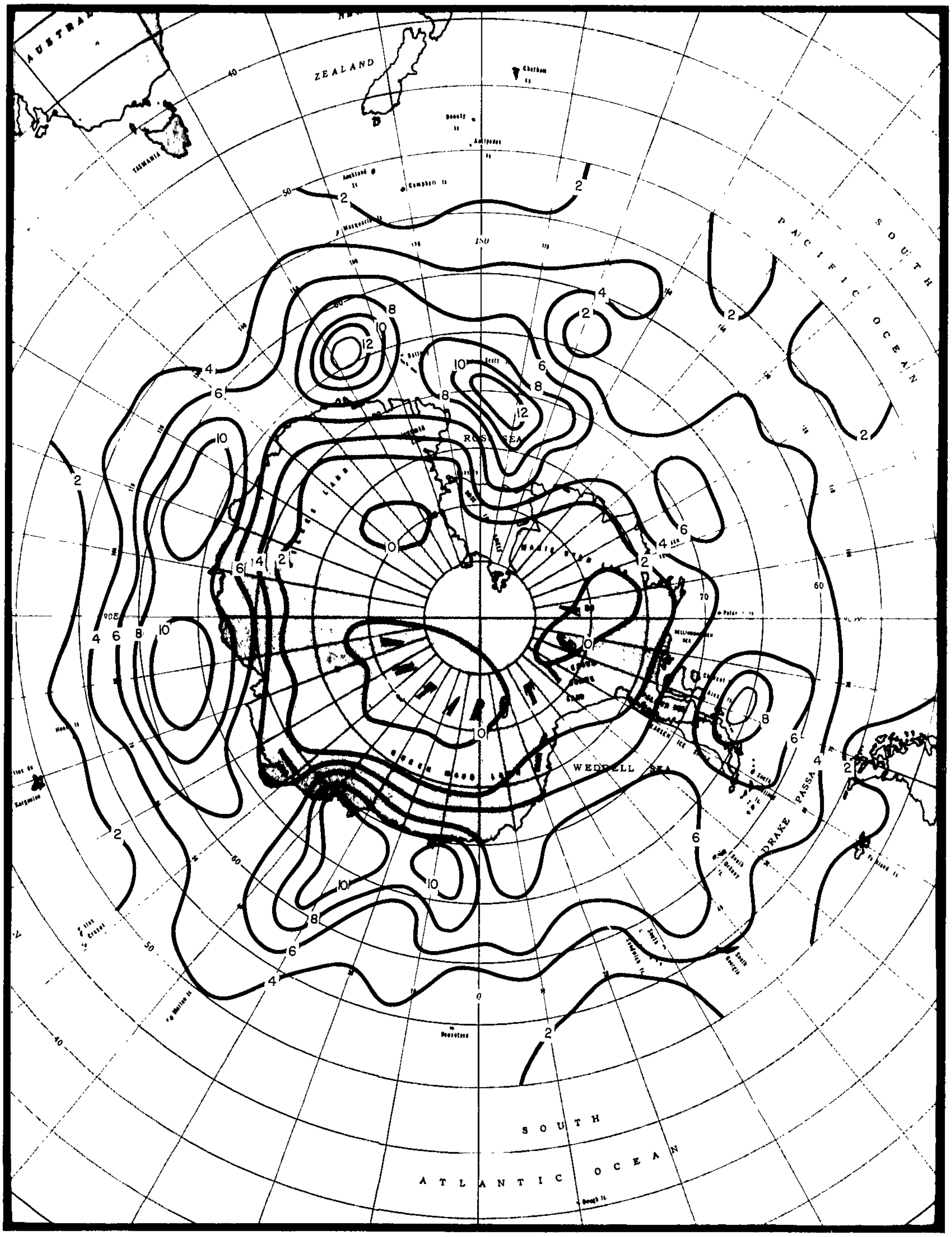

Figure 2.30. Average Percentage Frequency of Occurrence of Low Centers for Fall.

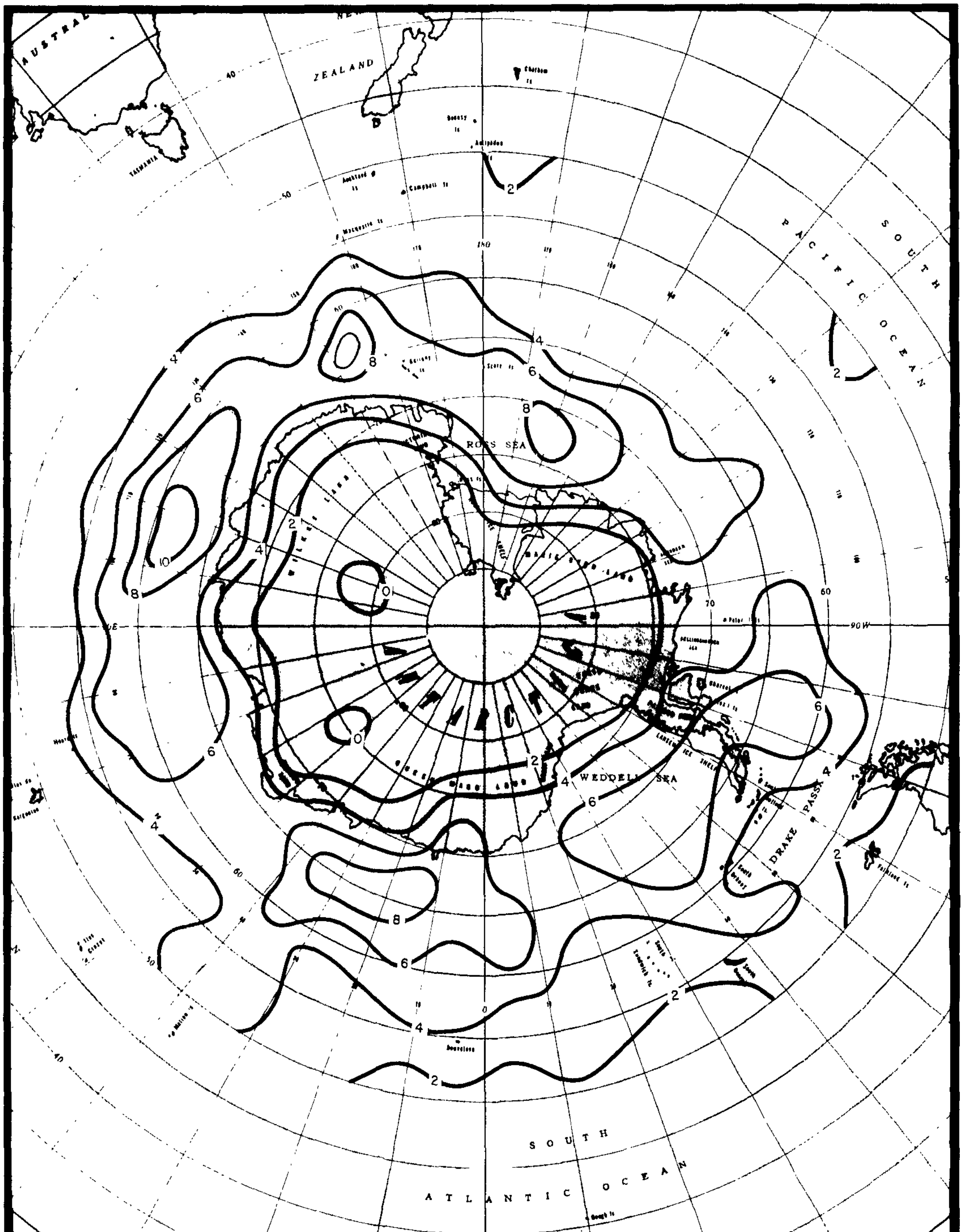

Figure 2.31. Average Percentage Frequency of Occurrence of Low Centers for Winter.

3. ANTICYCLONES

3.1 Review of Previous Studies

As early as the beginning of the 20th century it was generally accepted that surface pressure increased to the south of a barometric minimum located near 60° S. [5]. This implied the existence of a surface anticyclone in the vicinity of the continent of Antarctica. The early workers in this field were faced with the dilemma of postulating a theory of anticyclonic circulation that would include a mechanism whereby the immense snowfields and glaciers of the elevated interior regions of Antarctica could be replenished by precipitation.

The antarctic anticyclone was, at first, thought to exist only around the periphery of the continent. This view was held by Shaw [26] and Meinardus [19], both of whom expressed some doubt as to the existence of a high pressure cell over the interior of Antarctica. In addition, Meinardus, as reported by Court [5], asserted that "the antarctic anticyclone, so much discussed in the past, is a pressure distribution peculiar to the lower atmospheric strata only, appearing with distinctness only in the sea level pressure distribution."

In later years numerous theories regarding the antarctic anticyclone were set forth by Simpson [27], Barkow [4], Kidsin [13], Hobbs [8], Serra and Ratisbonna [25], and Palmer [21] in which a common feature appears to be agreement as to the existence of a relatively shallow anticyclone as a rather permanent feature of the interior of the continent.

Data gathered by meteorologists of the U. S. Navy's Operation Highjump [1] support this idea. It is beyond the scope of this report to consider these theories individually as regards their differences and similarities or, for that matter, their validity in the light of more recent data; however, the reader is referred to Court [5] and Hofmeyr [9] for excellent summaries of the works cited in this chapter, as well as some that were omitted.

On the basis of synoptic charts covering a 12-year period, Schmitt [24] found that anticyclones with a central sea level pressure of at least 1020 mb, tended to occur in three favored meridional sectors south of 50° S.

The greatest number of high centers of the specified intensity occurred in the Falkland sector, defined as including the area between 30° W. and 90° W., and south of the Falkland Islands. A minimum of high centers were observed during the summer months (3), while the other three seasons were about equal in number of occurrences (16, 16, and 14). The next area most frequently occupied by high centers is located in the sector south of New Zealand. The seasonal variation in this sector was found to be similar to that in the Falkland sector but the frequency of occurrence was only one-half as great. The third favored sector, with a frequency of occurrence of high centers much less than in the Falkland sector, is located to the south of Kerguelen Island. According to Schmitt, "They (anticyclones) are completely absent over the oceanic regions between South Georgia and Mcquarie Islands, except around 60° E. to 80° E." This paper also suggests that the entire coastline of Antarctica as well as the South Pacific Ocean are regions where anticyclones frequently exist, although the charts available at the time were inadequate to verify their existence.

If Schmitt's statistics are summed over all sectors for each season, autumn will have the largest number of anticyclones in high southern latitudes and summer will have the fewest, with 33 and 9, respectively. However, even in the most favored regions, the frequency of occurrence of anticyclones results in a much smaller percentage frequency than was the case for cyclones, as indicated earlier in this report. This is supported by Gibbs' [6] statement that "On rare occasions distinct anticyclonic cells occur south of latitude 50° S. ..... ."

The results of Lambs' [15] study indicate that during the years of 1951 through 1954, the region between the coast of Antarctica and 60° S. was largely devoid of anticyclones. The area between 50° and 60° S., in general, showed an increase in anticyclonic activity from winter to summer, largely as a result of the displacement to the south of the midlatitude belt of maximum percentage frequency of occurrence of high centers. In addition, Lamb deduced that "quasi-stationary anticyclones south of 40° S. are limited to positions over Antarctica and to just three sectors of the surrounding ocean; namely, (1) from close to the south coast of Australia to a wider range of latitudes in the western Pacific, probably as far as the region near 60° S. and 120° to 140° W., (2) near the tip of South America and southeast thereof, over the region of the Scotia Sea from 60° to 65° S., and (3) in the region southeast of South Africa.''

Van Loon [30] compiled data showing the daily positions of high pressure centers in the half hemisphere centered on the South Pacific Ocean during the summer seasons of 1955 - 1956 and 1956 - 1957, when numerous weather reports were available due to the resumption of whaling in the area. The results obtained showed that highs tended to be most frequent to the east and southeast of New Zealand and in the Amundsen Sea and western Ross Sea regions. These conclusions were substantiated by the appearance of ridges in the same locations on the mean sea level pressure chart drawn for the same time period.

3.2 Percentage Frequency of Occurrence of High Centers

Figure 3.1 depicts the monthly average (for 6 years) of the total number of high pressure centers south of 50° S. latitude, accumulated from independent daily weather charts. It is evident that highs are most frequent during the month of March when an average total number (summed from individual daily weather charts) of 82 centers appear. This constitutes about 12 percent of the average yearly total as contrasted to November, the month of least anticyclonic activity, when an average total of 36 daily-analyzed high centers are observed, representing only 5 percent of the yearly total.

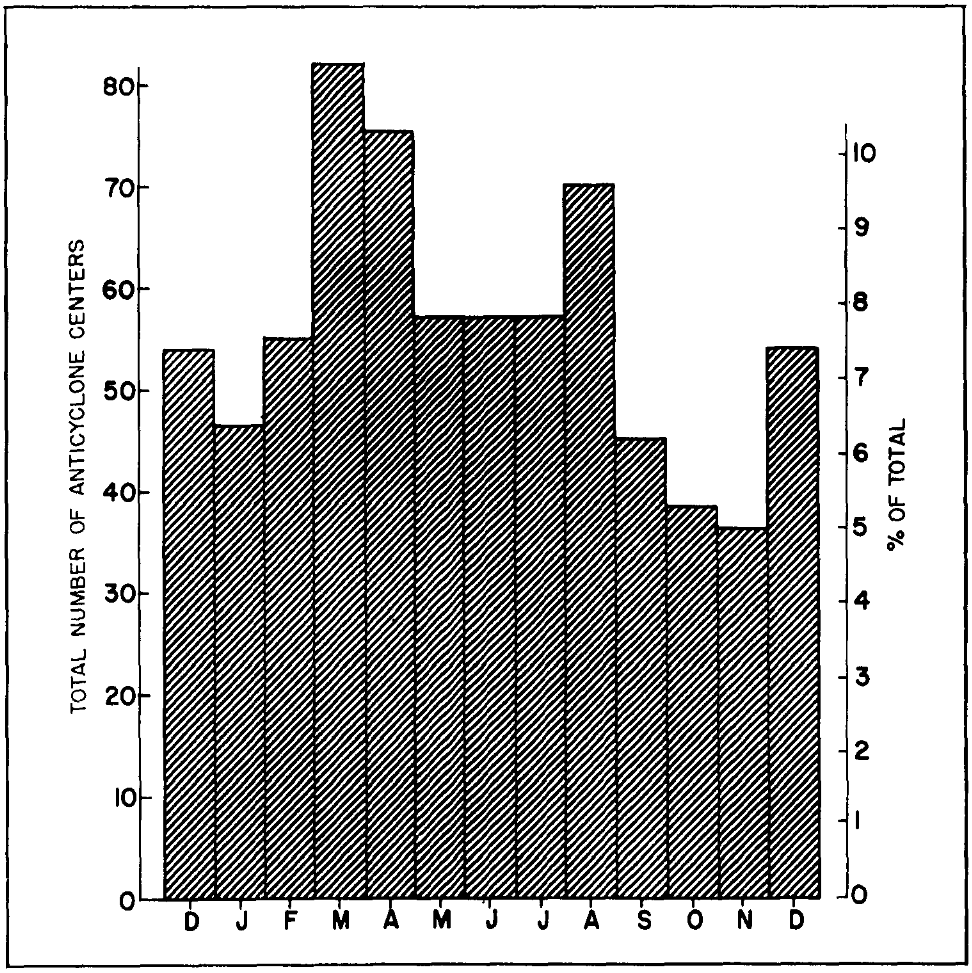

Figure 3.1. Average of the Total Number of Anticyclone Centers, Accumulated from Daily Surface Weather Charts, South of 50°S. Latitude by Month. August 1948 through December 1952 and January 1960 through August 1961.

When the data are stratified by season (fig. 3.2) fall is the time of the year for the most frequent existence of high pressure centers south of the 50th parallel--followed by winter, summer, and spring in descending order. Almost twice as large a percentage of the average yearly total of high centers occurs in fall (32 percent) than in spring (17 percent).

Comparing figures 2.1 and 3.1, it can be observed that although, on the average, there is a large preponderance of low pressure centers over high pressure centers during all times of the year, there is a much larger percentage variation from month to month in the total number of anticyclones as compared to cyclones.

With the exception of December, there is a similarity in the average yearly distribution of low and high pressure centers. In both cases relative maxima occur in March and August and relative minima are noted in spring; early winter and early spring for lows and late spring in the case of highs. In addition, the seasonal distributions of low and high centers (figs. 2.2, 3.2) are quite similar, except for the summer season which is the season of maximum occurrence of cyclones, whereas the average number of anticyclones is a relative minimum during this season. The preceding discussion is concerned only with the temporal variation of the total number of low and high pressure centers that were noted to occur, on the average, throughout the Southern Hemisphere south of the 50th parallel. The comparisons noted are, of course, not necessarily valid at any particular location within the region under discussion. The temporal variations of anticyclonic activity in certain specific areas will be discussed in the remainder of this chapter.

The charts of monthly and seasonal percentage frequency of occurrence of high centers (figs. 3.3 through 3.18) indicate the primary area of anticyclonic activity to be the eastern part of the Polar Plateau, "East Antarctic Plateau". The Ross Sea, Marie Byrd Land, Wilkes Land,

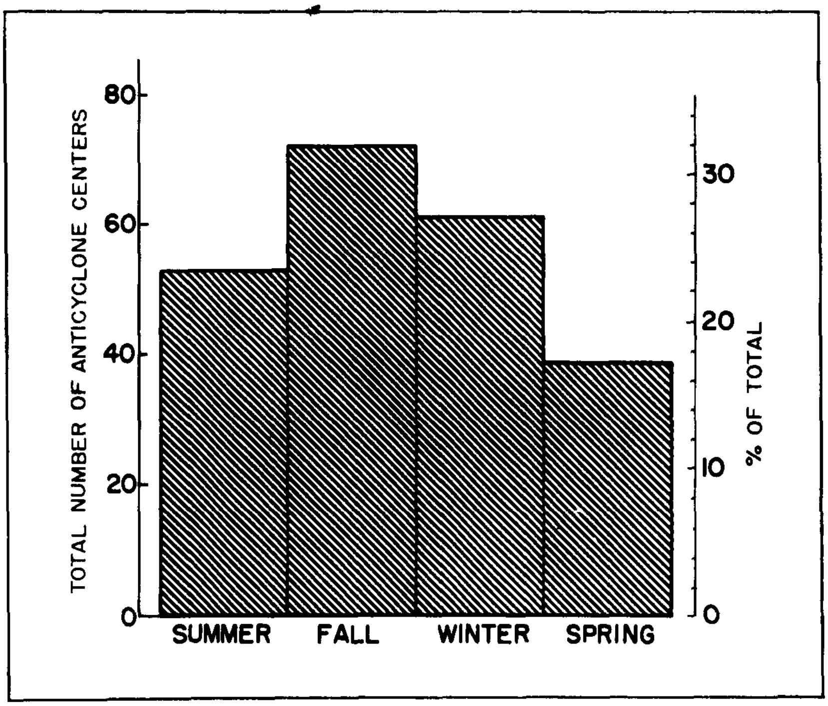

Figure 3.2. Average of the Total Number of Anticyclone Centers, Accumulated from Daily Surface Weather Charts, South of 50°S. Latitude by Season.

the Weddell Sea, Ellsworth Highland, and the Amundsen Sea are regions of secondary maxima of frequency of occurrence of high centers.

3.2.1 East Antarctica

South of 50°S., high pressure centers are most frequent over the "East Antarctic Plateau", that portion of the continent between 0° and 130° E. longitude.

The isopleths of the percentage frequency of occurrence of high centers (figs. 3.3 through 3.18) indicate that there is considerable monthly and seasonal variation in the magnitude and, to a lesser degree, location of the maximum observed value in east Antarctica.

The magnitude varies from a maximum of 19.4 percent in early fall (March) to a minimum of 5.0 percent in late spring (November). The seasonal charts show that the maximum percentage frequency of high centers is twice as large in fall as in any of the other three seasons.

The position of the maximum percentage frequency of occurrence of high centers shifts from its most northerly position in winter to the spring, summer, and fall positions as it moves progressively farther to the south. There is approximately 5 degrees of latitude between the extreme positions of winter (82°S.) and fall (87° S.).

During January, an area of relative maximum appears over the western portion of Wilkes Land near 77°S. and in February is found over eastern Wilkes Land.

3.2.2 West Antarctica and the Southern Oceans

Several areas of relative maxima of percentage frequency of occurrence of high centers are present during December (fig. 3.14) the beginning of austral (Southern Hemisphere) summer. The most pronounced concentration of high centers is located over the Weddell Sea, on the lee side of the Palmer Peninsula, and extends northeast to the vicinity of the South Sandwich Islands. Another region of relative maxima during early summer is oriented meridionally across Marie Byrd Land and extends northward to about 65°S. latitude and 110°W. longitude. Relative maxima also appear at this time over the oceans south of Tasmania and New Zealand.

As summer progresses from December into January, there is a general decrease in percentage frequency of occurrence of high centers throughout the regions under discussion, with the exception of the maximum located over the Weddell Sea and increases over Edith Ronne Land, Ellsworth Highland, and eastern Marie Byrd Land. The most persistent feature of the distribution of anticyclonic centers during the summer season is the maximum located at the base of the Palmer Peninsula and extending from south of the South Orkney Islands to the eastern part of the Marie Byrd Land.

With the onset of the fall season, maxima reappear south of Australia and in the South Pacific Ocean, as do the relative maxima in the Weddell Sea and South Sandwich-South Orkney Islands areas. These last two areas, however, show a decrease in anticyclonic activity during the remaining 2 months of fall, while west Antarctica (with the exception of Marie Byrd Land) is the scene of increased activity as winter approaches.

The data for March indicate a maximum in percentage frequency of occurrence of high centers in the vicinity of McMurdo Sound, and in April a short lived area of maximum appears in the region bounded by 50°S. and 65°S. latitudes, and 10°E. and 10°W. longitudes. The Weddell Sea, Edith Ronne Land, the South Pacific Ocean, and the ocean south of Australia are regions of relatively frequent occurrence of high pressure centers during the fall season.

The most pronounced features of the first 2 months of winter (June and July) are the reestablishment of the areas of relative maxima of percentage frequency of occurrence of high centers in the Weddell Sea and Marie Byrd Land regions, as well as the appearance of a new area of relative maximum anticyclonic activity in the eastern Ross Sea. By the end of winter, however, anticyclonic activity in west Antarctica and the southern oceans has decreased to a great extent. The chart for winter shows that, in the region under discussion, the areas of maximum frequency of anticyclonic centers are (in the decreasing order of magnitude of frequency) Marie Byrd Land, eastern Ross Sea, and Weddell Sea.

With the exception of a few small areas, anticyclones tend to occur less and less frequently throughout September and October, the first 2 months of spring. This trend of decreasing frequency of occurrence continues through November, when most of the region under discussion experiences a yearly minimum in the number of anticyclone centers observed. An exception is the southern Edith Ronne Land - Weddell Sea area.

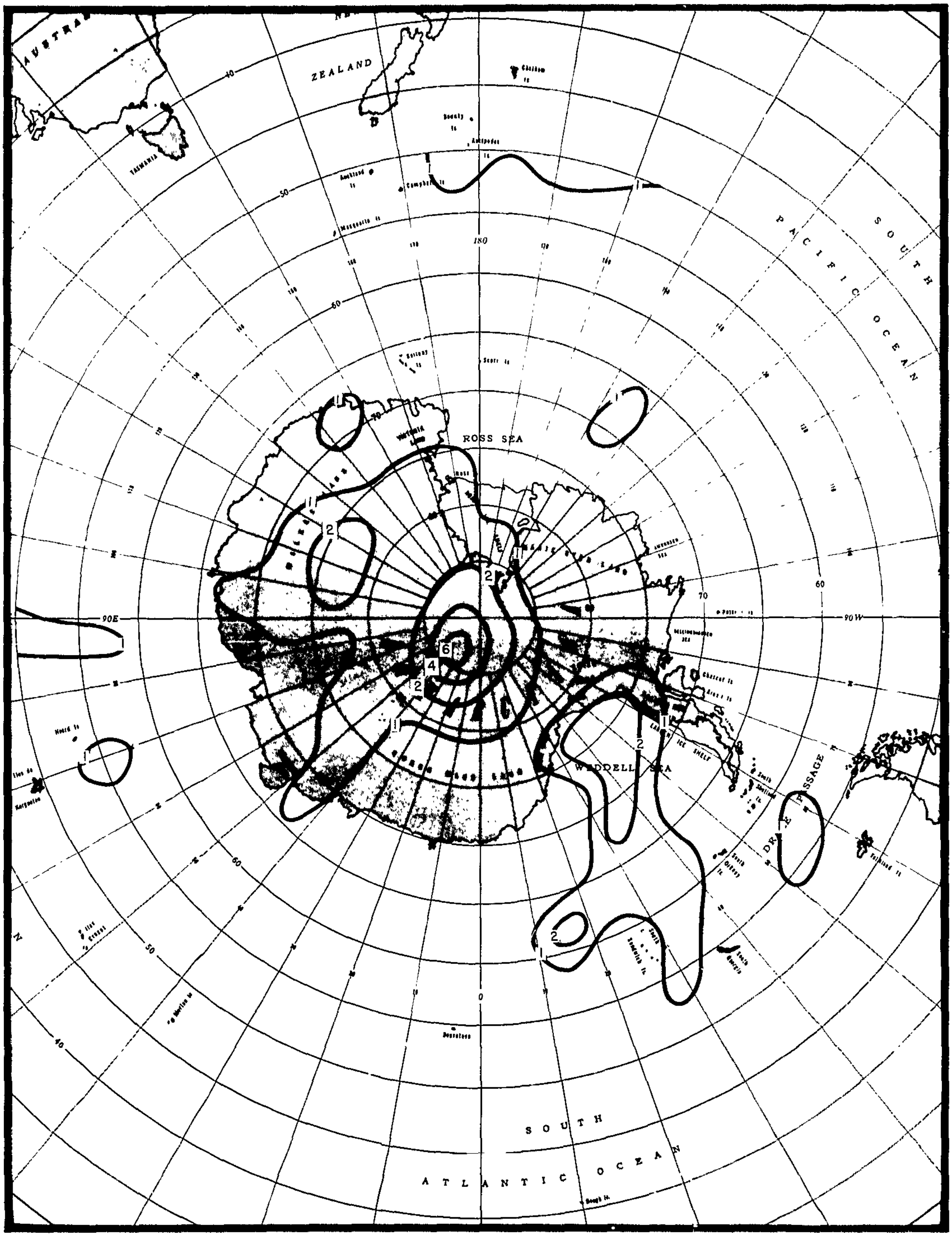

Figure 3.3. Percentage Frequency of Occurrence of High Centers for January.

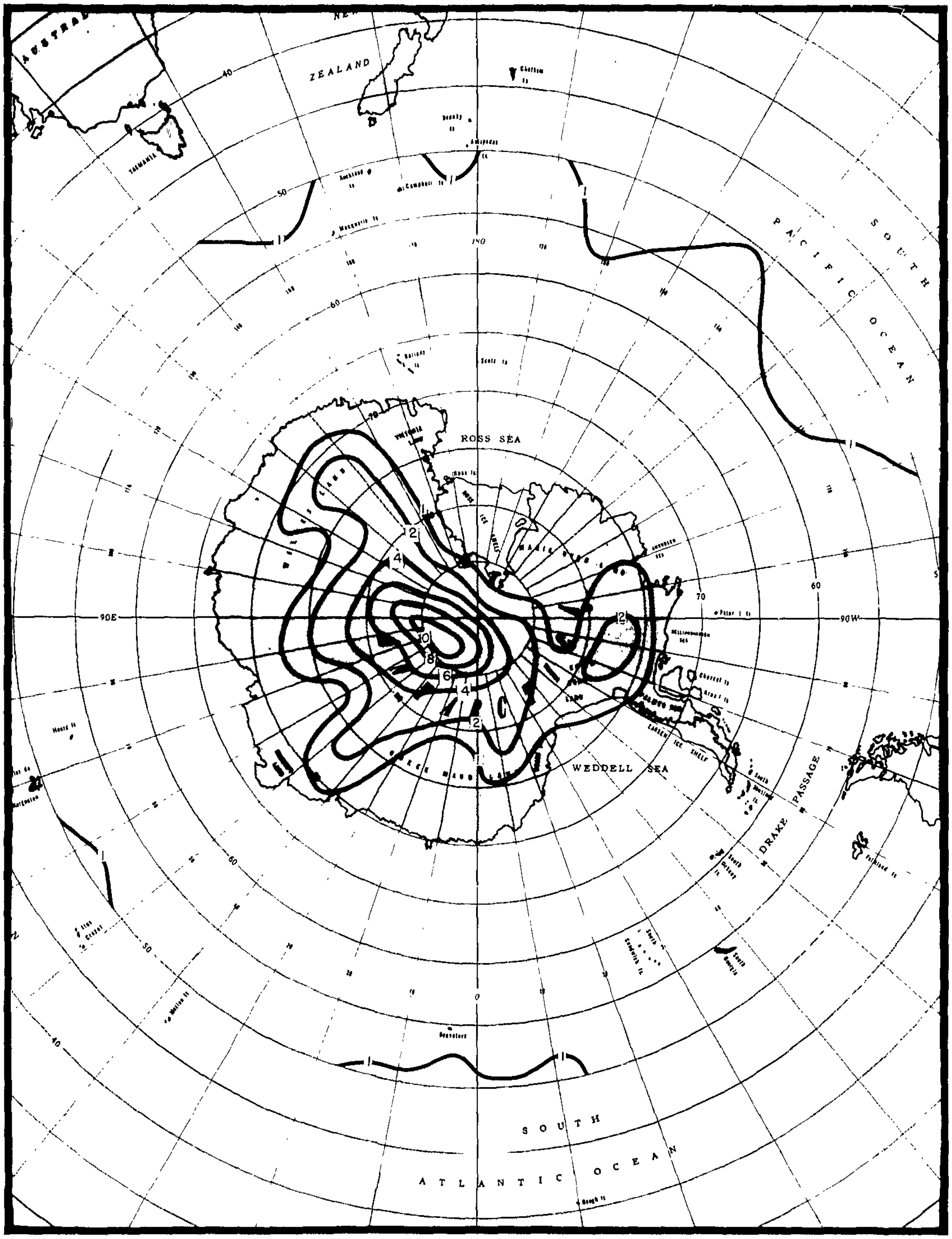

Figure 3.4. Percentage Frequency of Occurrence of High Centers for February.

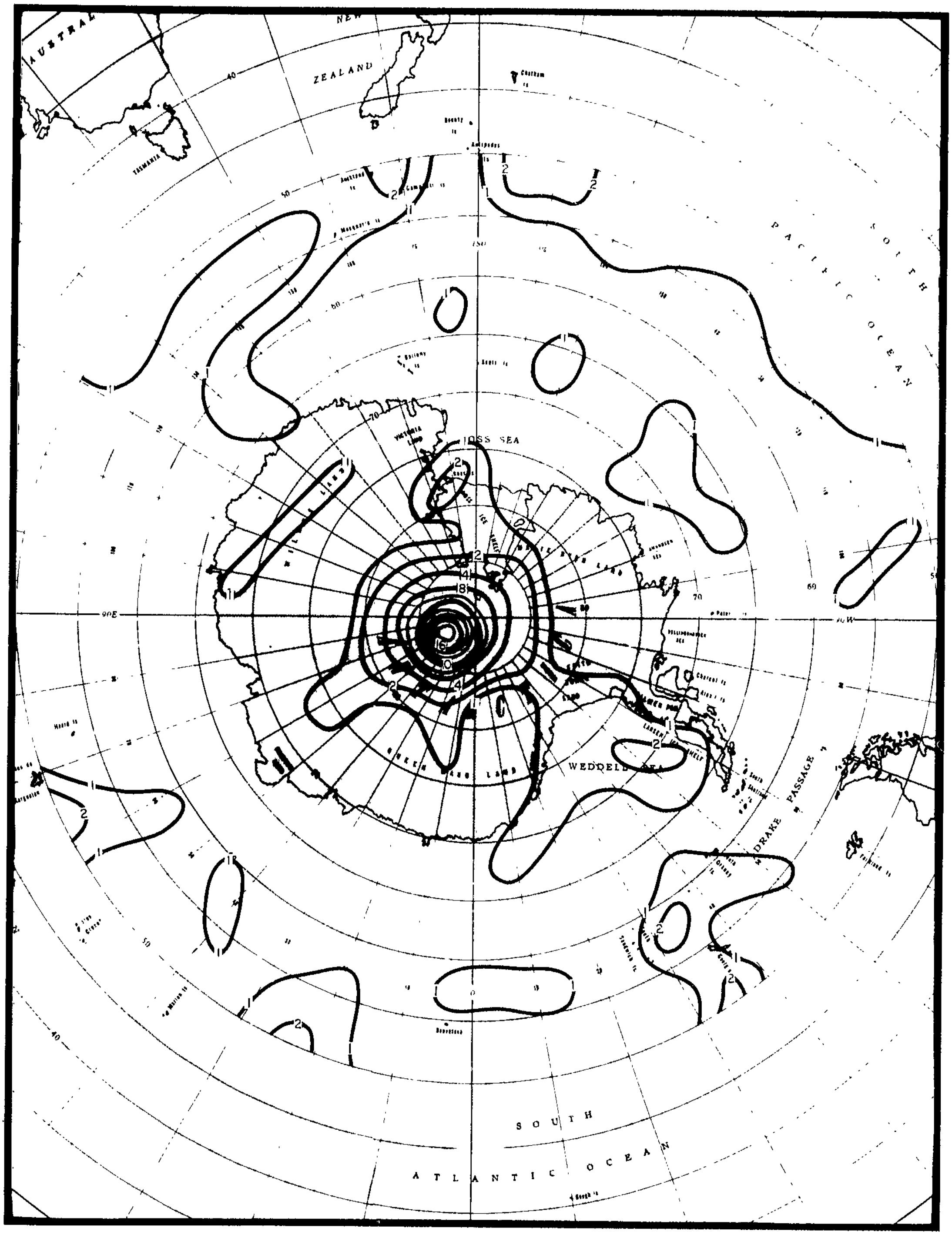

Figure 3.5. Percentage Frequency of Occurrence of High Centers for March.

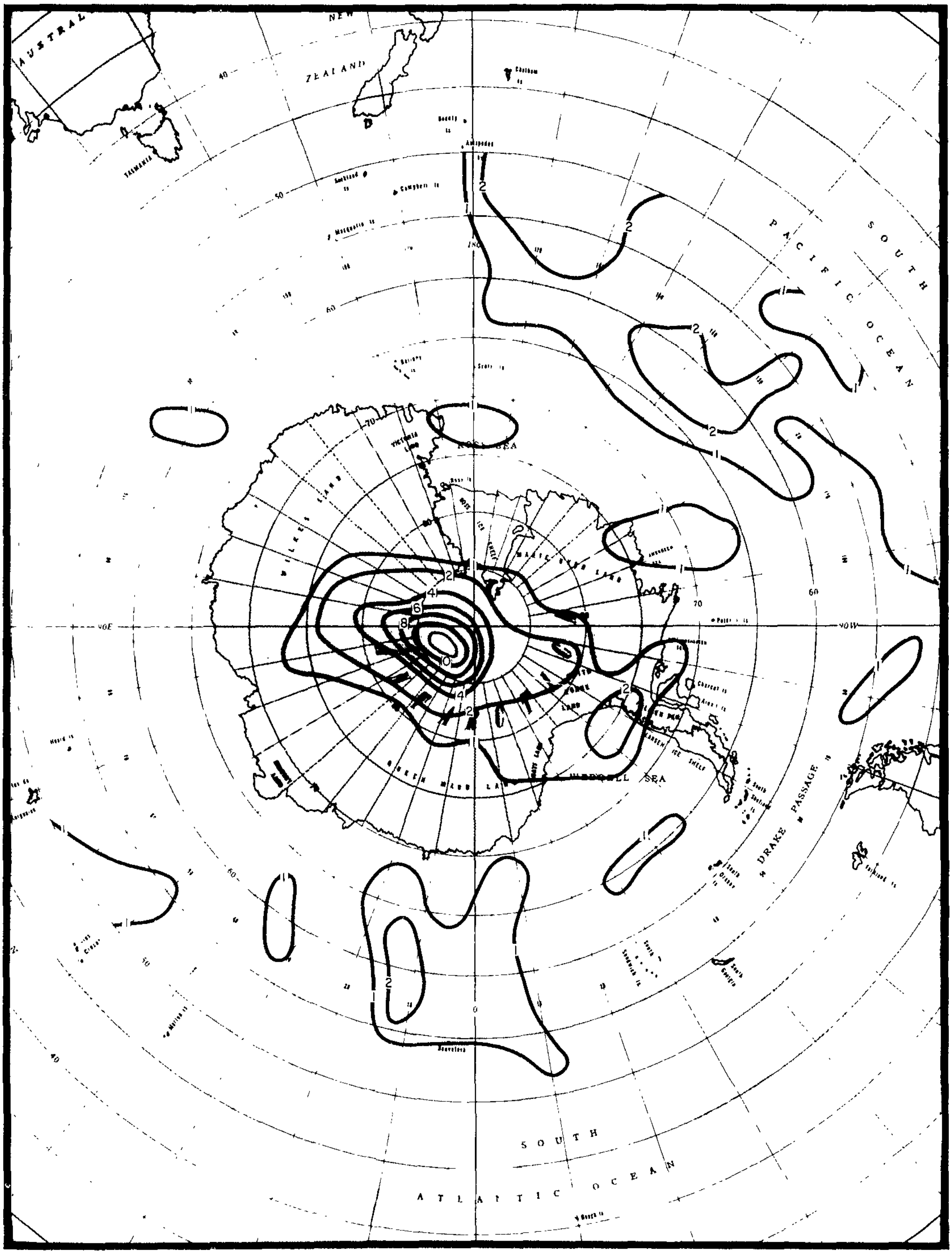

Figure 3.6. Percentage Frequency of Occurrence of High Centers for April.

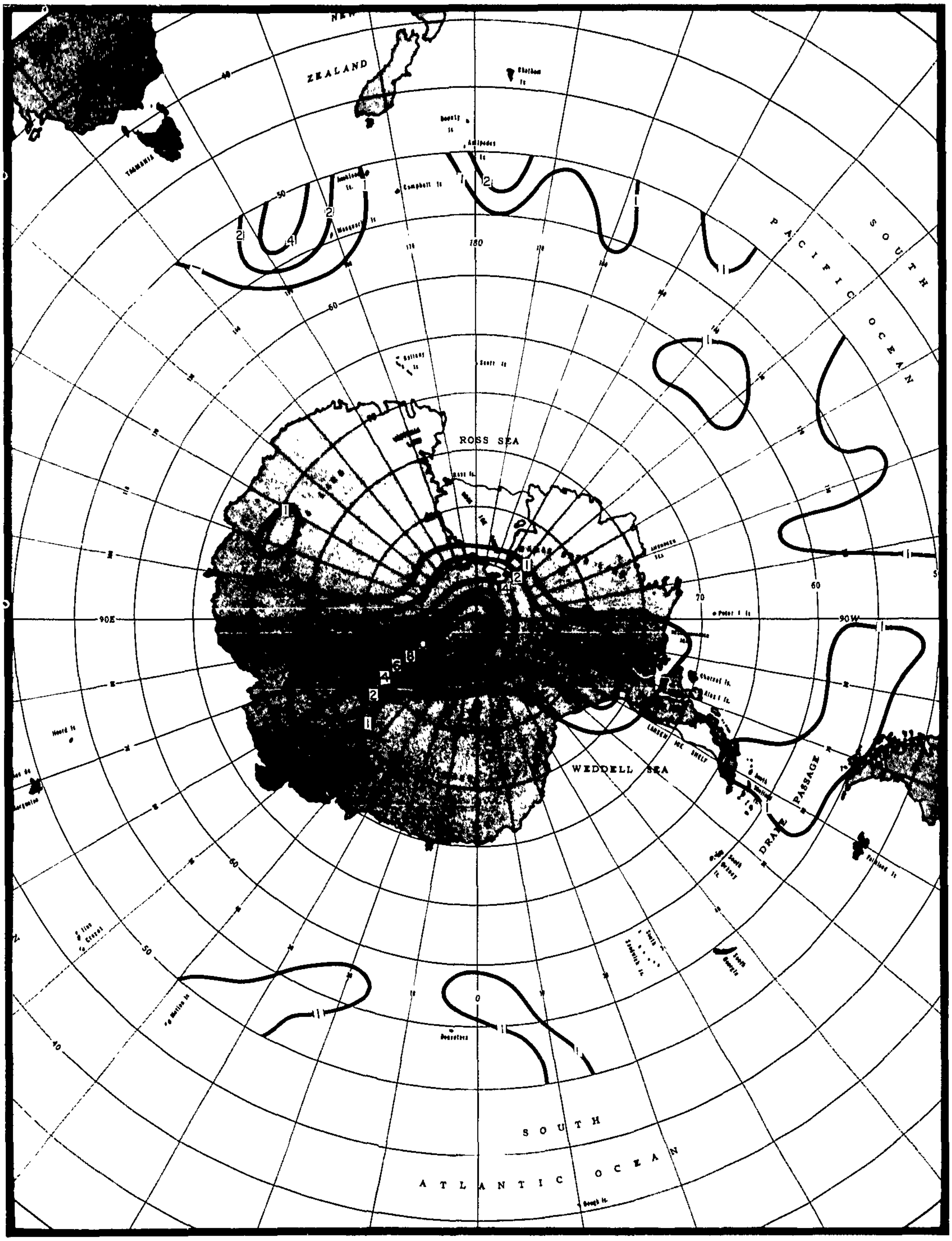

Figure 3.7. Percentage Frequency of Occurrence of High Centers for May.

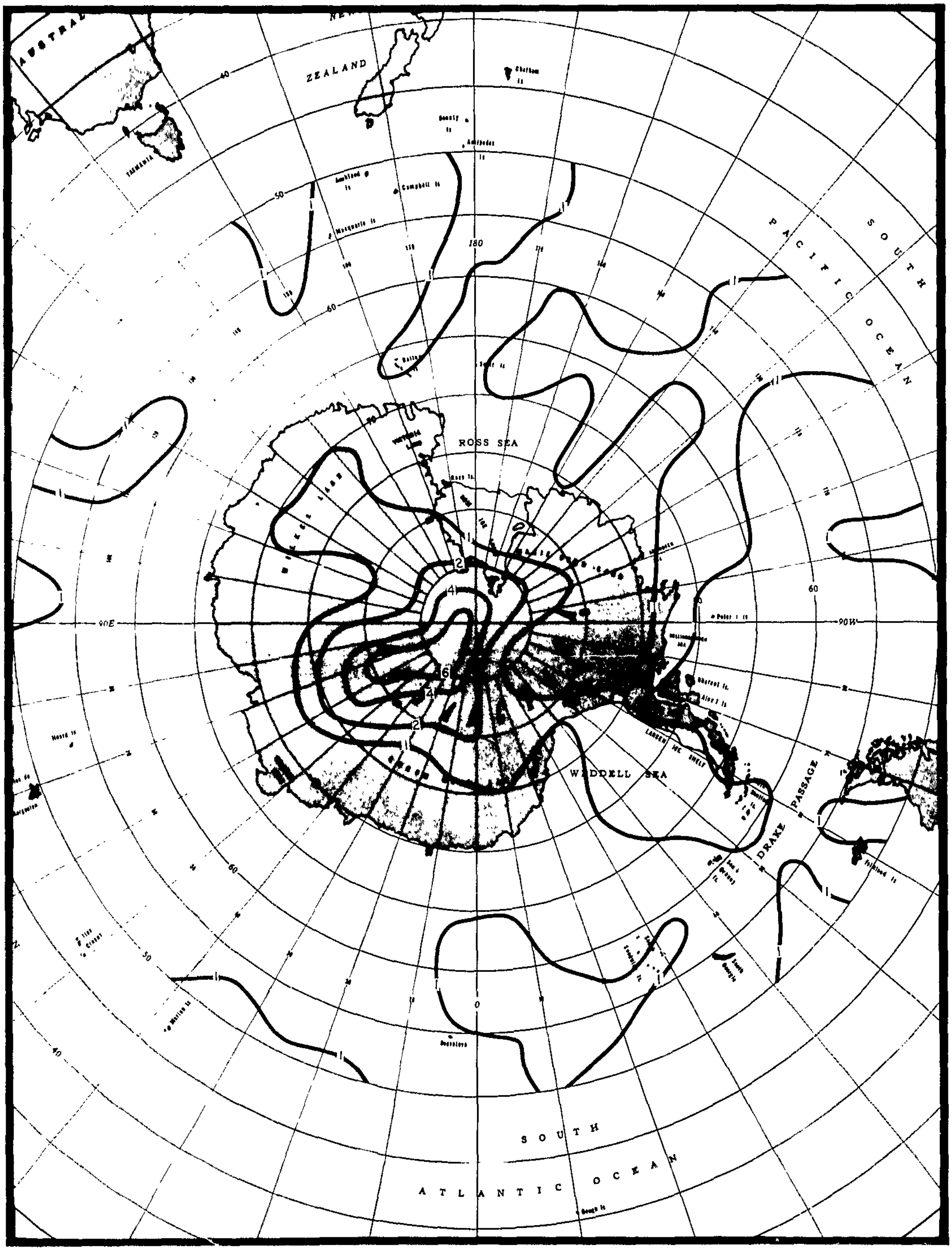

Figure 3.8. Percentage Frequency of Occurrence of High Centers for June.

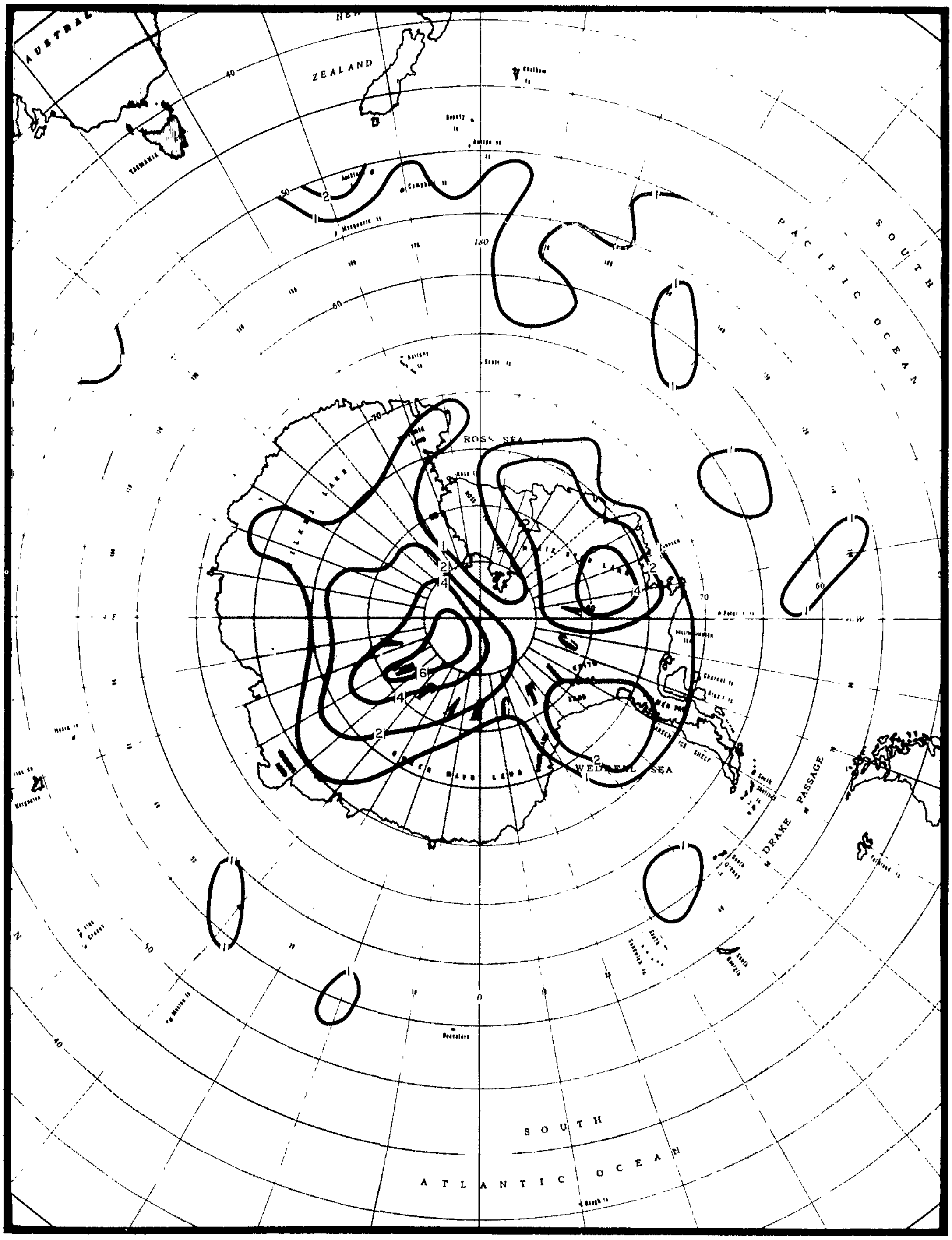

Figure 3.9. Percentage Frequency of Occurrence of <u>High</u> Centers for July.

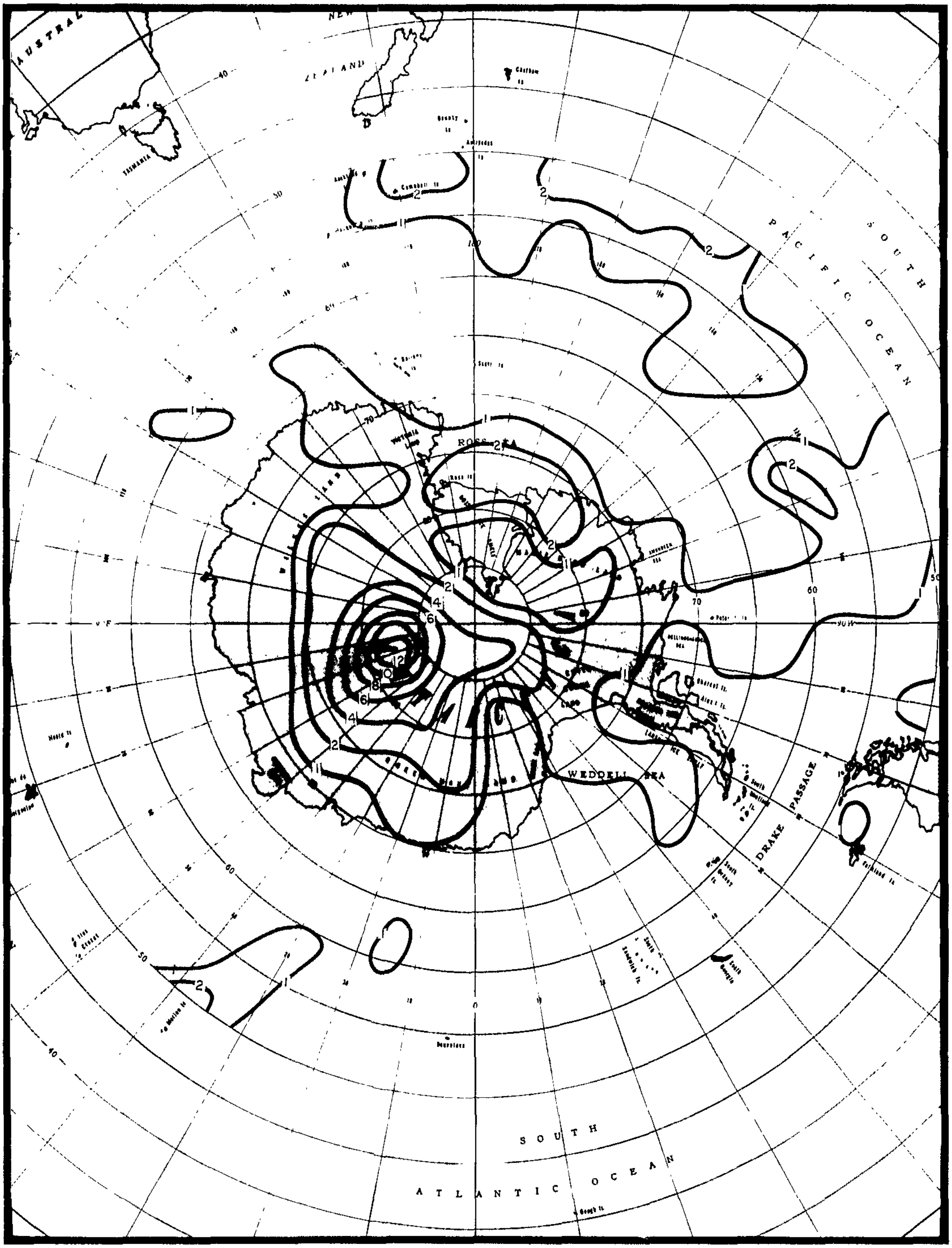

Figure 3.10. Percentage Frequency of Occurrence of High Centers for August.

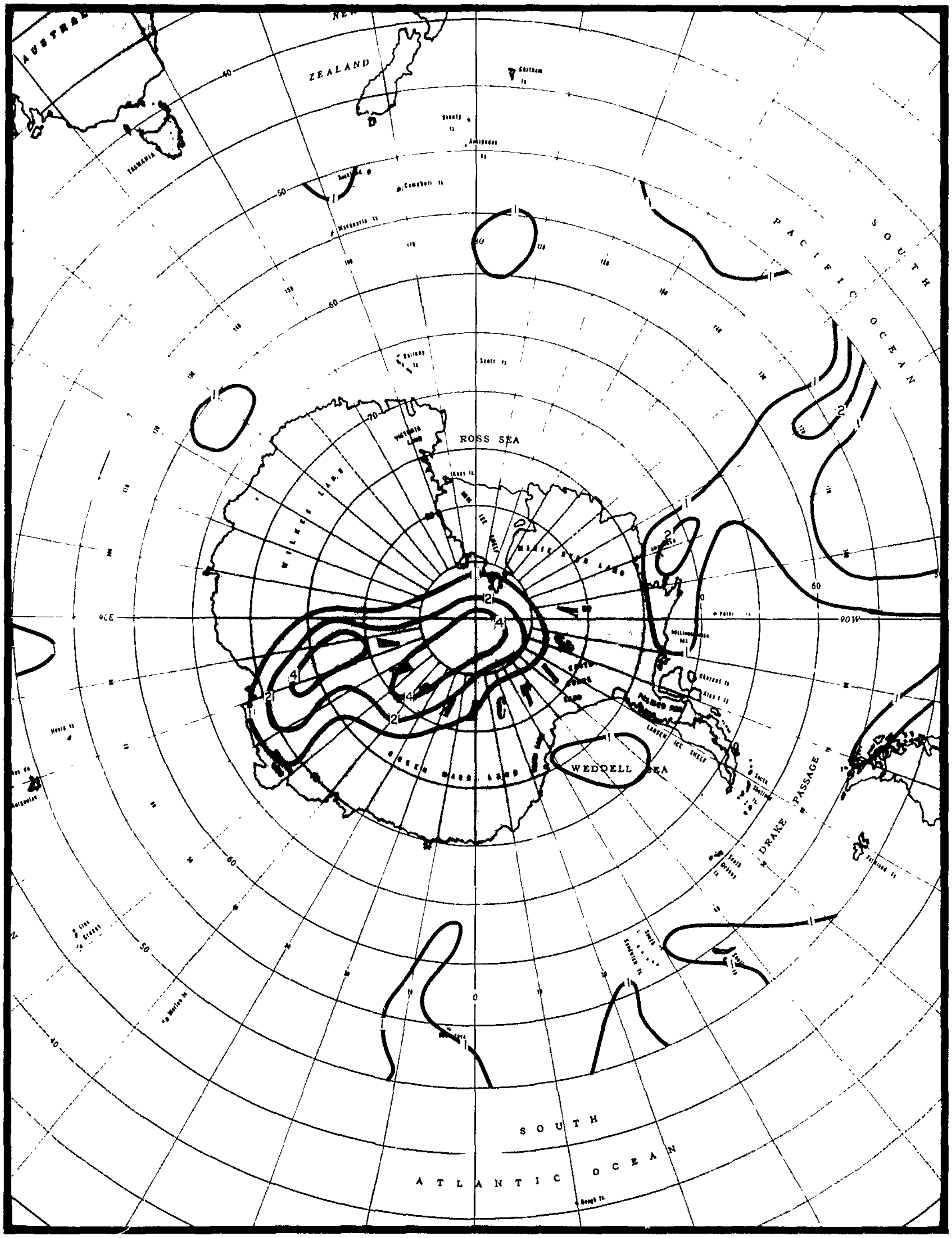

Figure 3.11. Percentage Frequency of Occurrence of High Centers for September.

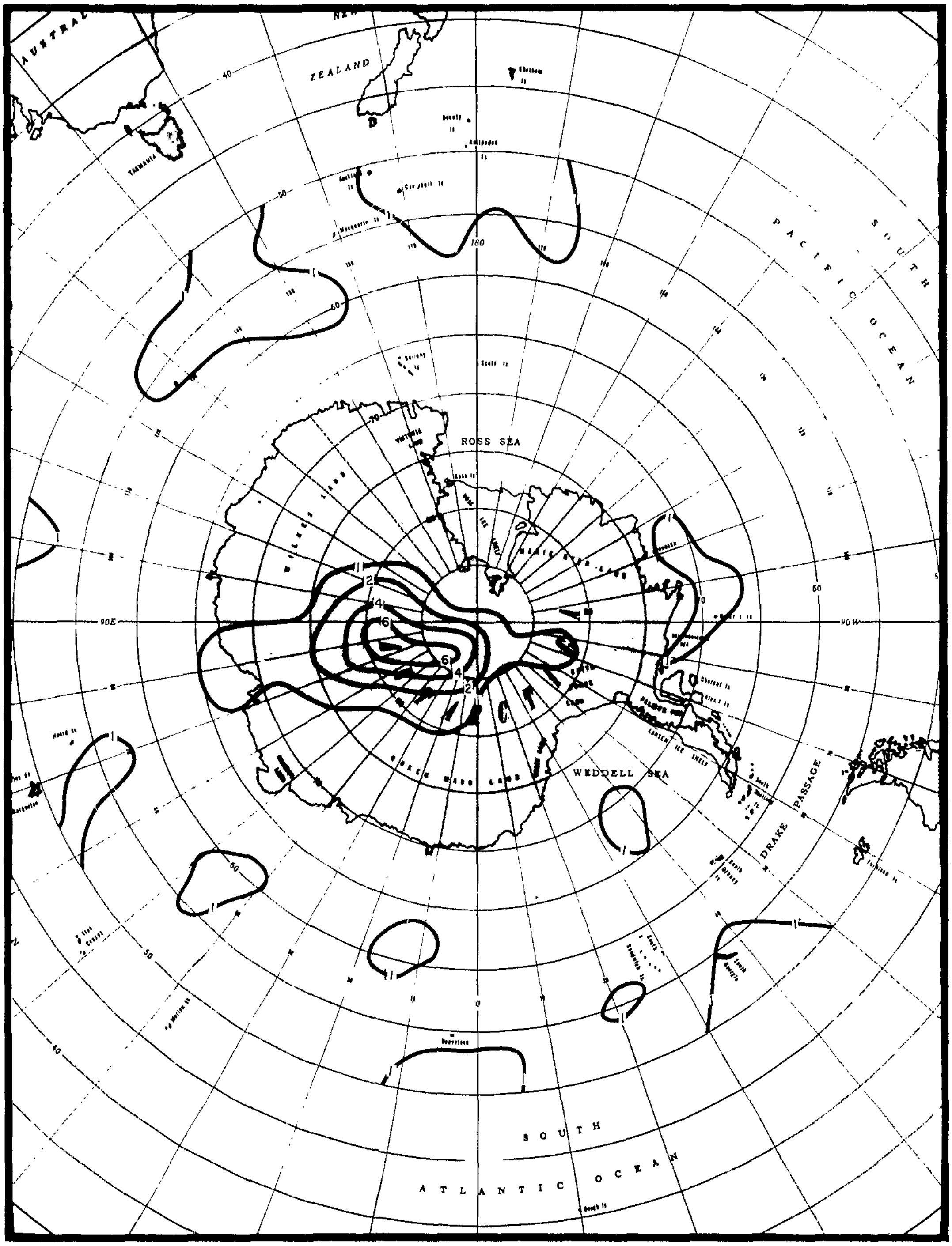

Figure 3.12. Percentage Frequency of Occurrence of High Centers for October.

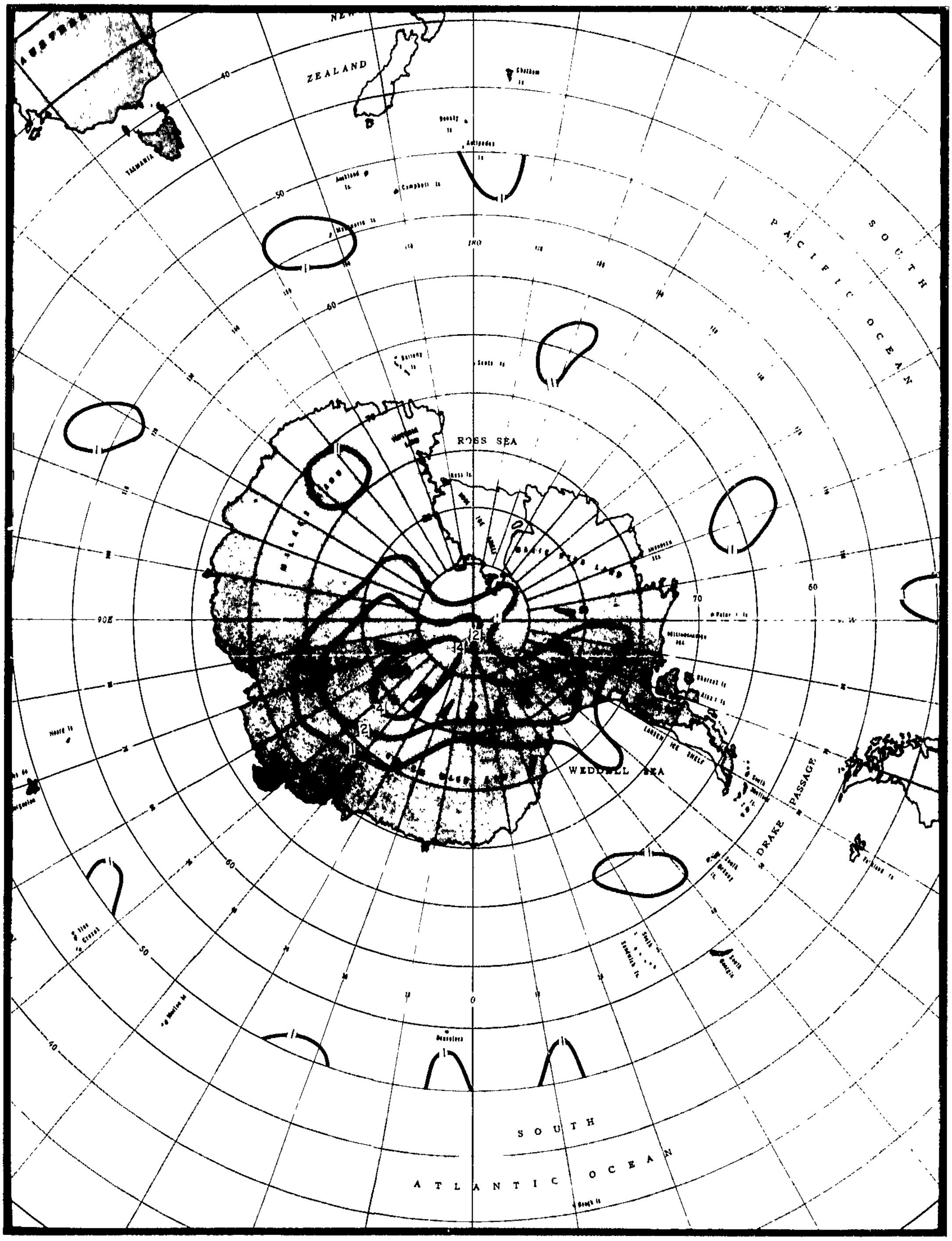

Figure 3.13. Percentage Frequency of Occurrence of High Centers for November.

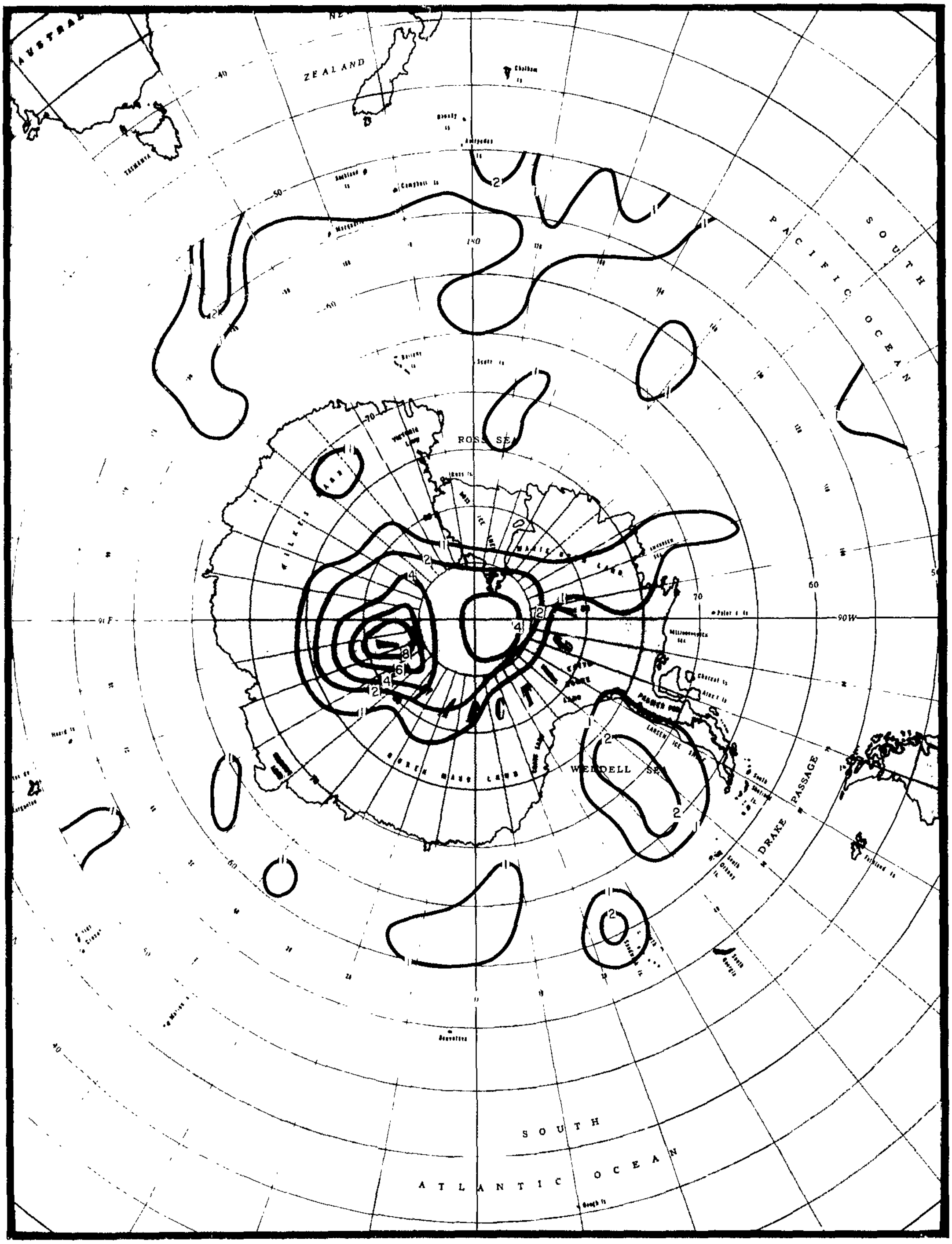

Figure 3.14. Percentage Frequency of Occurrence of High Centers for December.

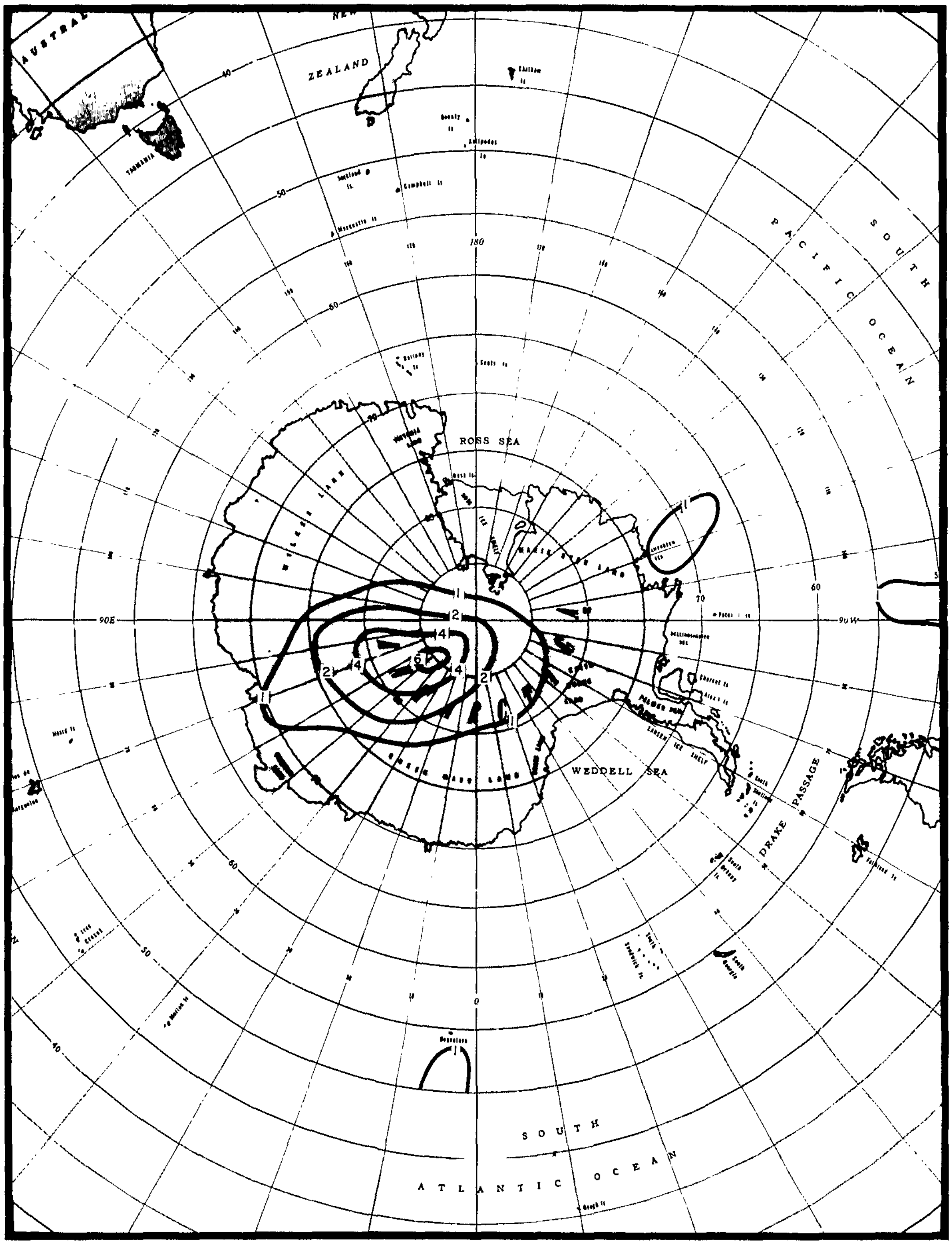

Figure 3.15. Percentage Frequency of Occurrence of High Centers for Spring.

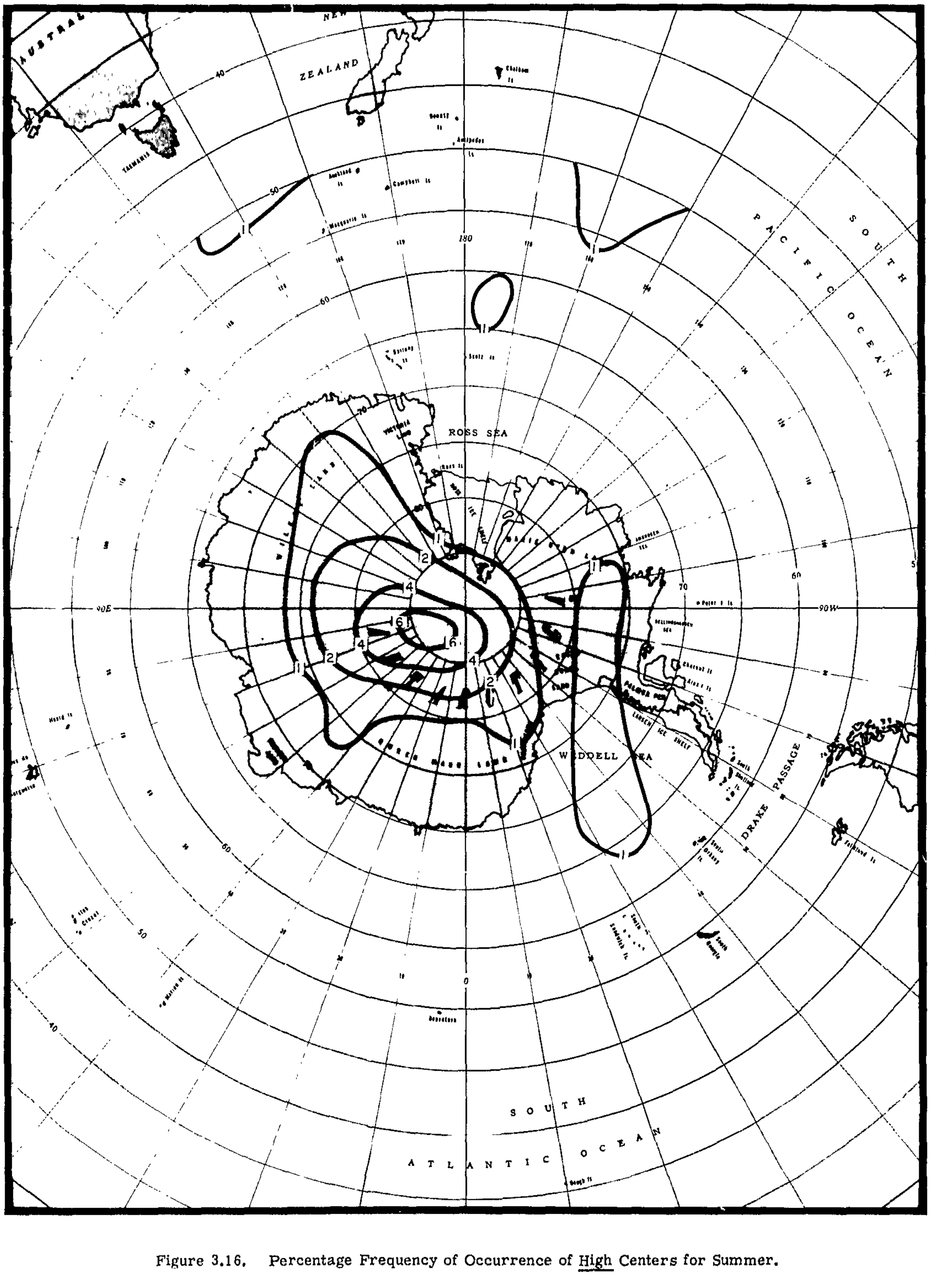

Figure 3.16. Percentage Frequency of Occurrence of High Centers for Summer.

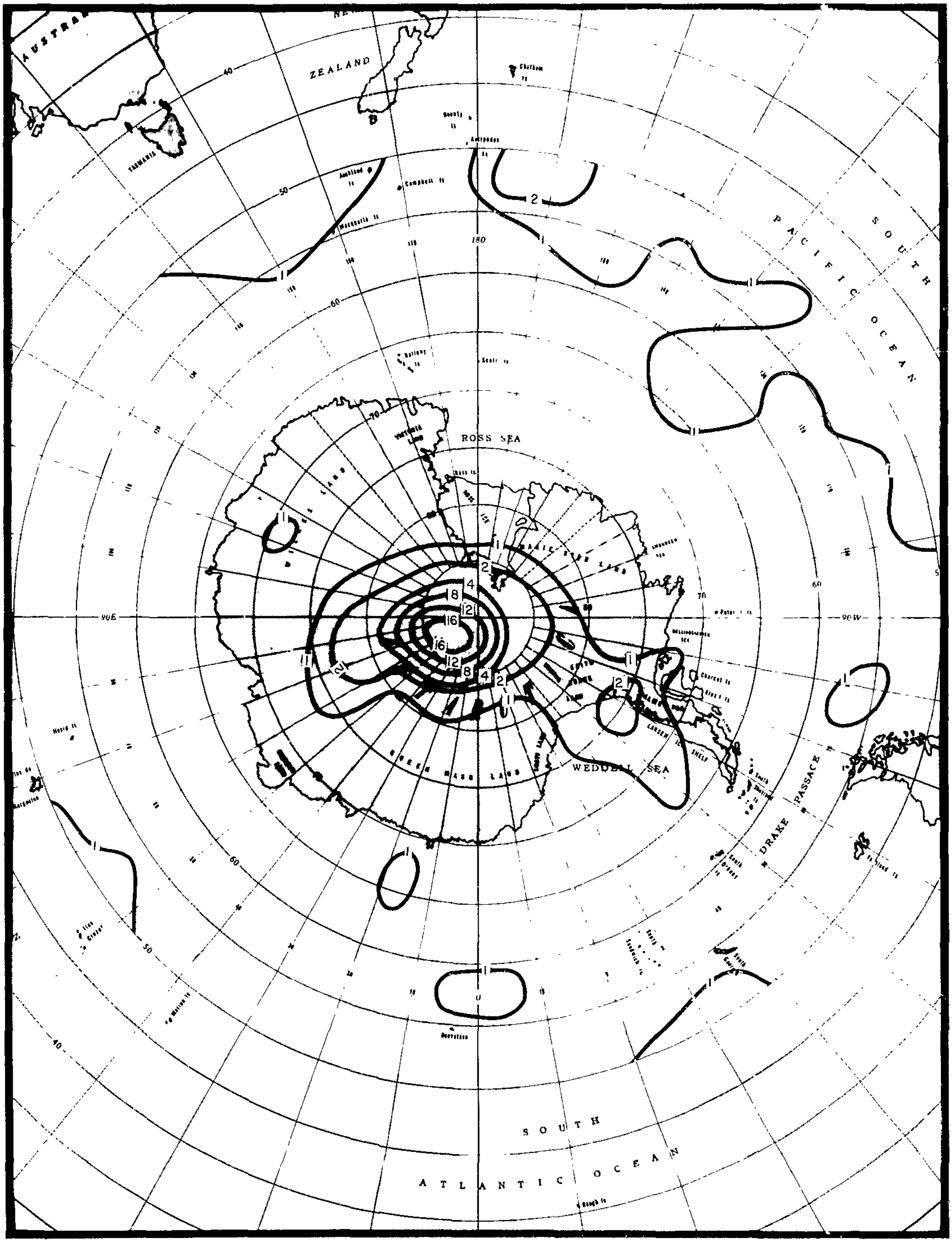

Figure 3.17. Percentage Frequency of Occurrence of High Centers for Fall.

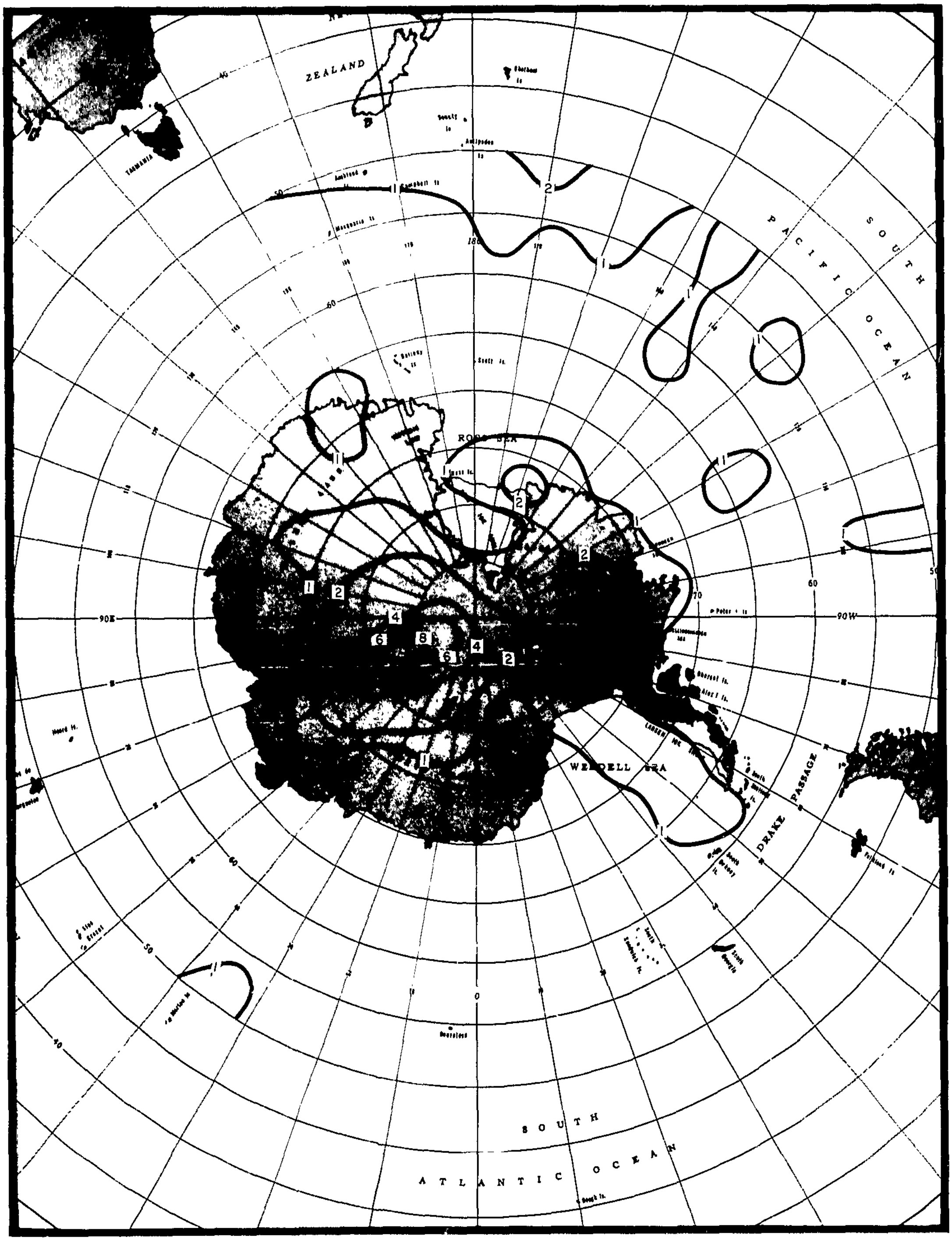

Figure 3.18. Percentage Frequency of Occurrence of High Centers for Winter.

4. RATE OF ALTERNATION

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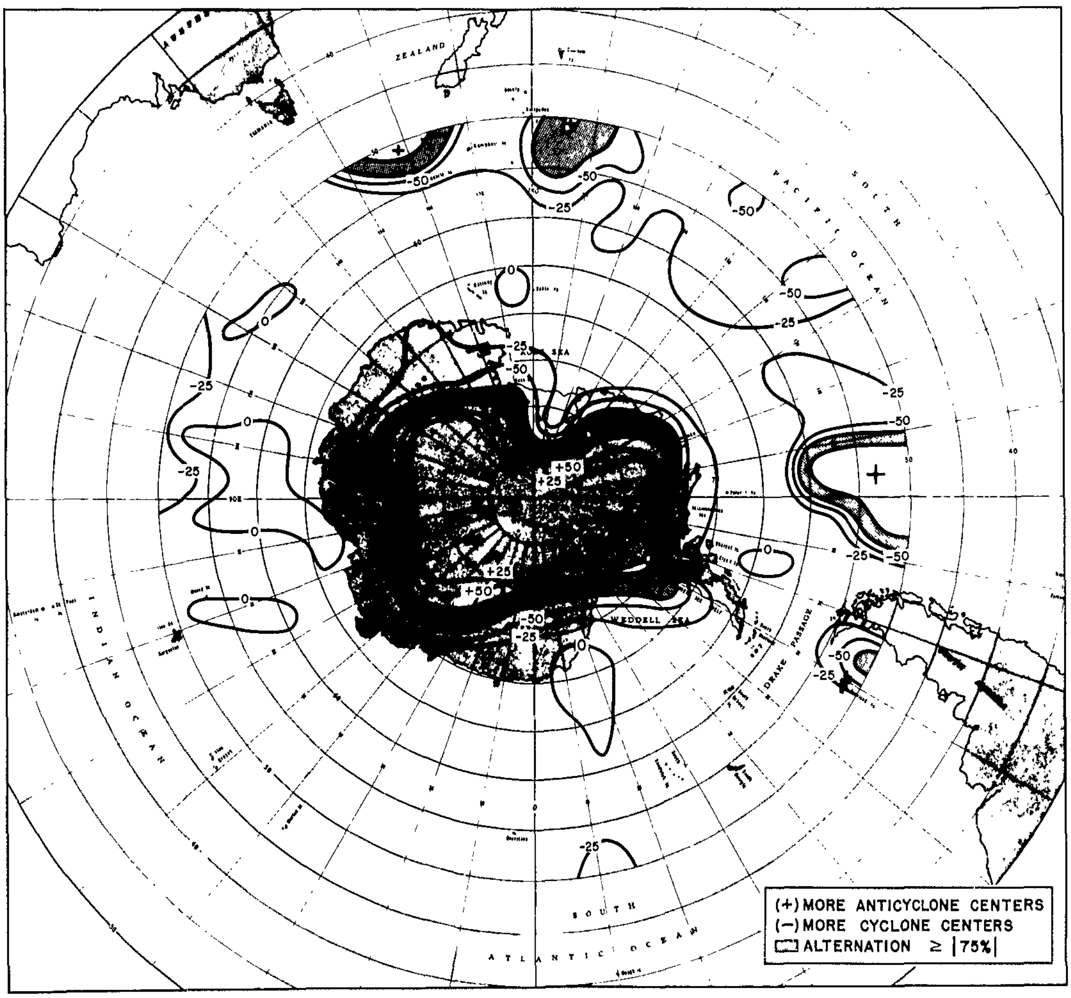
Summer and winter values of the rate of alternation have been computed and are presented in figures 4.1 and 4.2. Areas designated as plus are areas where more anticyclonic centers occurred than did cyclone centers, during the period of record. The rate of alternation is negative in areas where cyclone centers are more frequently observed than anticyclone centers,



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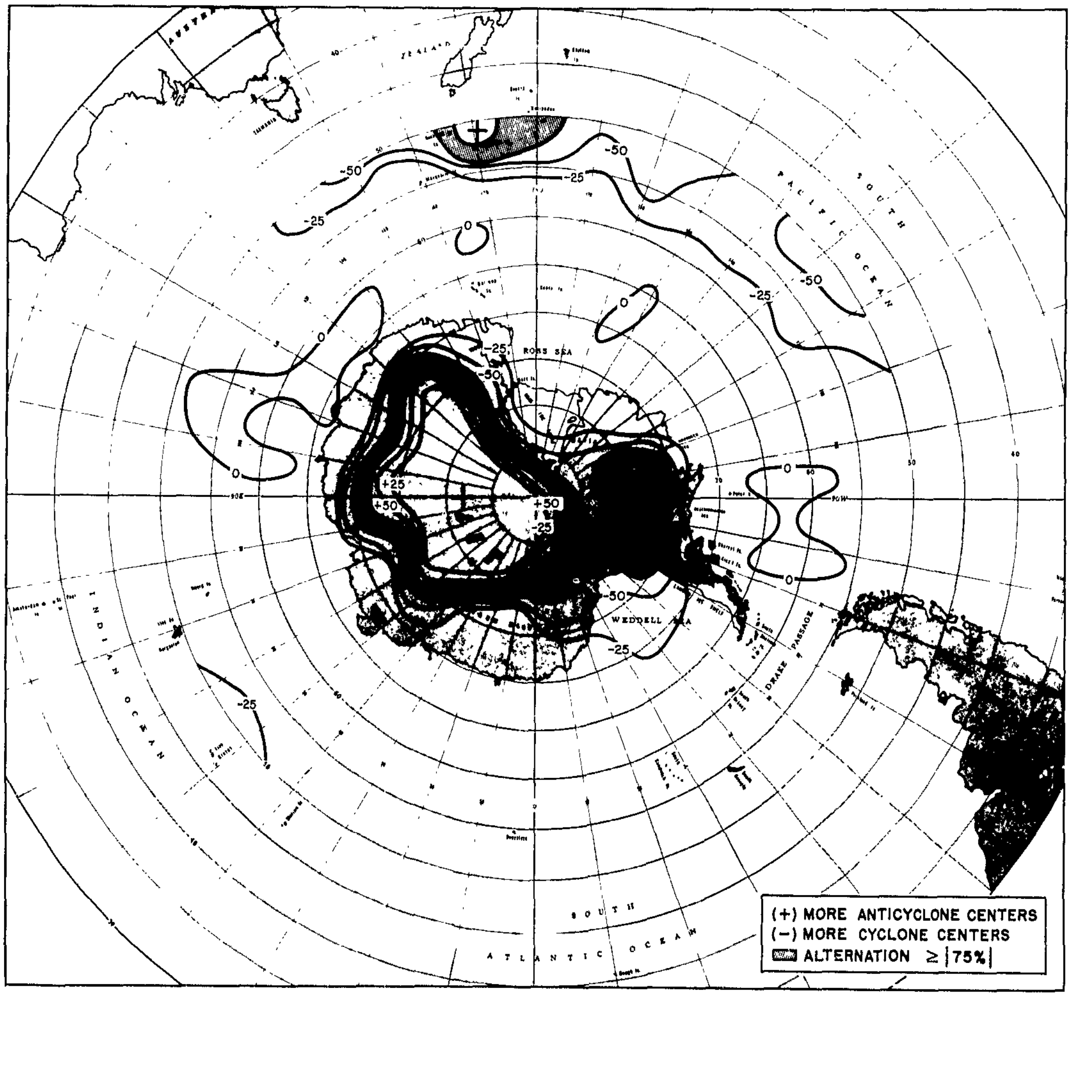

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5. SUMMARY AND CONCLUSIONS

The percentage frequency of occurrence of cyclones and anticyclones, as defined by Petterssen [22], was calculated for the Southern Hemisphere south of 50° S. by sectors measuring 5° of latitude on a side. These computations were performed by month and season for the period 1948 through 1952, 1960 through 1961. The results, after being isoplethed, served as the basis for drawing the following conclusions:

(1) The average number of cyclones occurring during any one month throughout the entire area south of the 50th parallel is greatest during December. Secondary maxima occur during March and August, while September is the time of the year with a minimum of cyclone occurrences. On a seasonal basis, the data indicate that a greater number of cyclones occur during summer and fall than during winter and spring, with the latter season exhibiting a minimum of cyclone activity.

(2) The total number of anticyclone centers observed in the Southern Hemisphere south of 50° S. is an order of magnitude less than the number of cyclones during any given month or season. The largest average number of anticyclone centers observed in the area occurs during March, with secondary maxima in April and August. More high centers were noted in fall than in any other season, with a minimum occurring in spring.

(3) The majority of anticyclone centers are found over the "East Antarctic Plateau", while there are several areas where relative maxima of percentage frequency of cyclone centers occur.

(4) With few exceptions, cyclones tend to occur in more southerly latitudes in winter than in summer. The main exception is the area extending from 50° E. to 160° E. longitude, where a slight seasonal shift of cyclones to more northerly latitudes is noted in winter. Spring is the time of year when cyclones are found in their most equatorward positions.

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(6) The main center of anticyclone activity located over the "East Antarctic Plateau" is found approximately 5° of latitude farther north in winter than in fall. This shift takes place along the 60th meridian.

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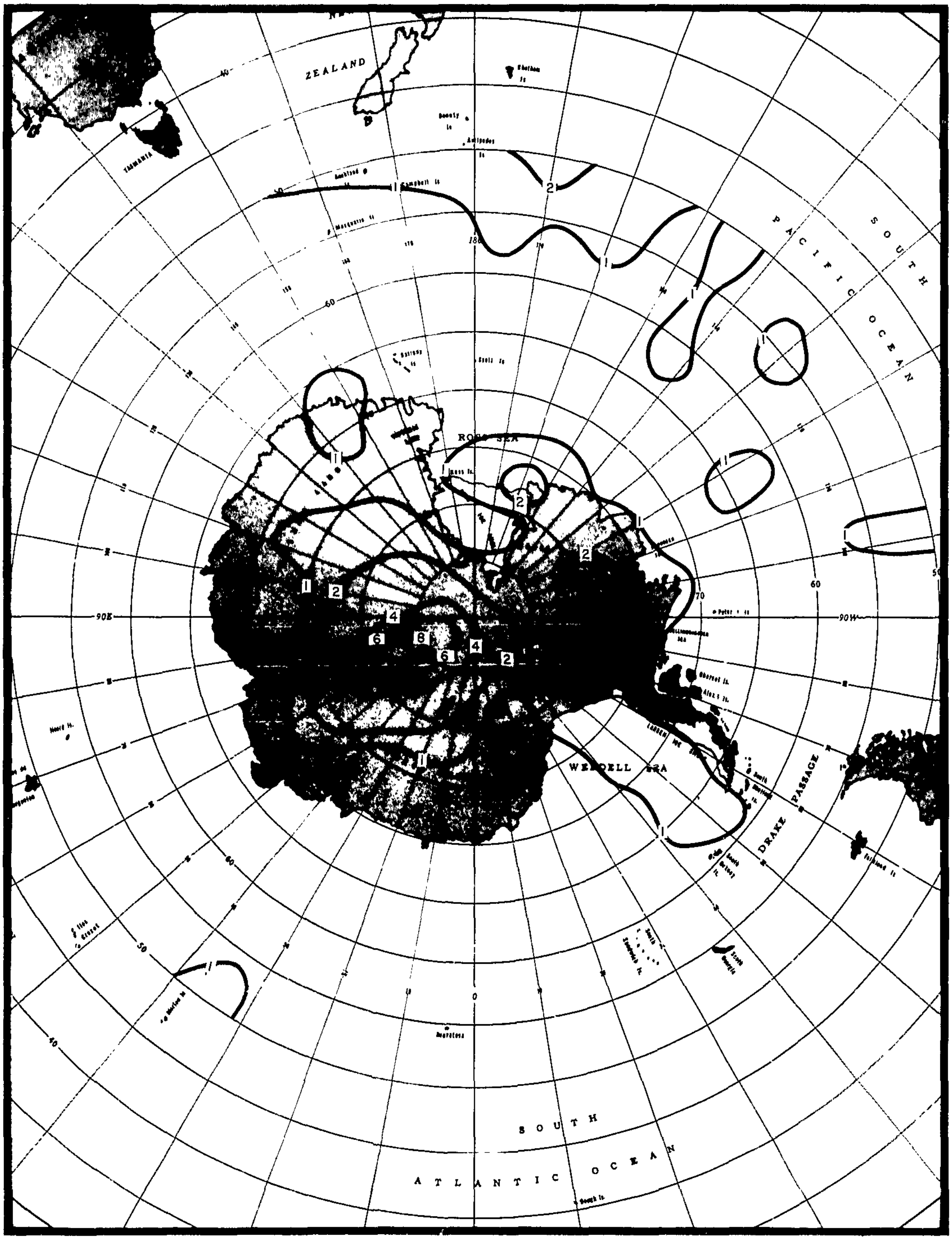

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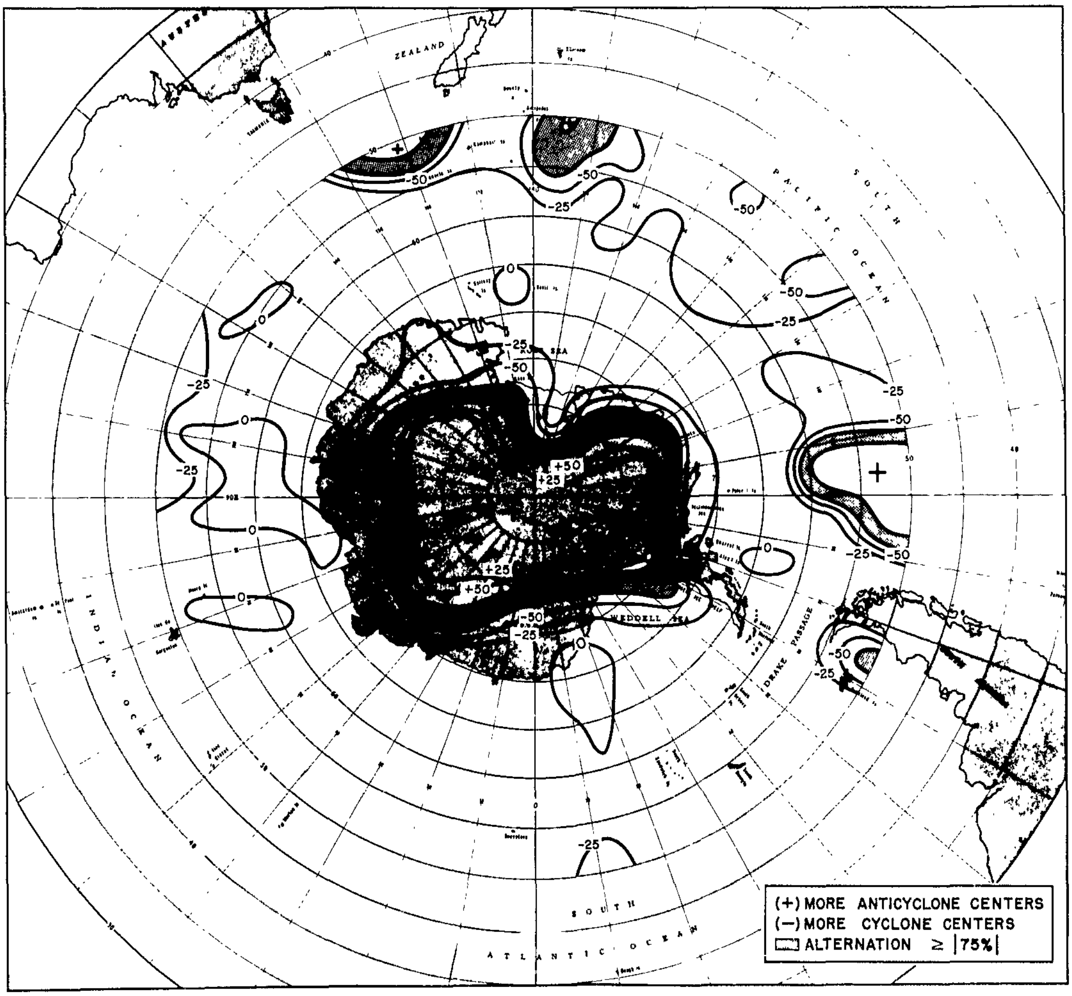

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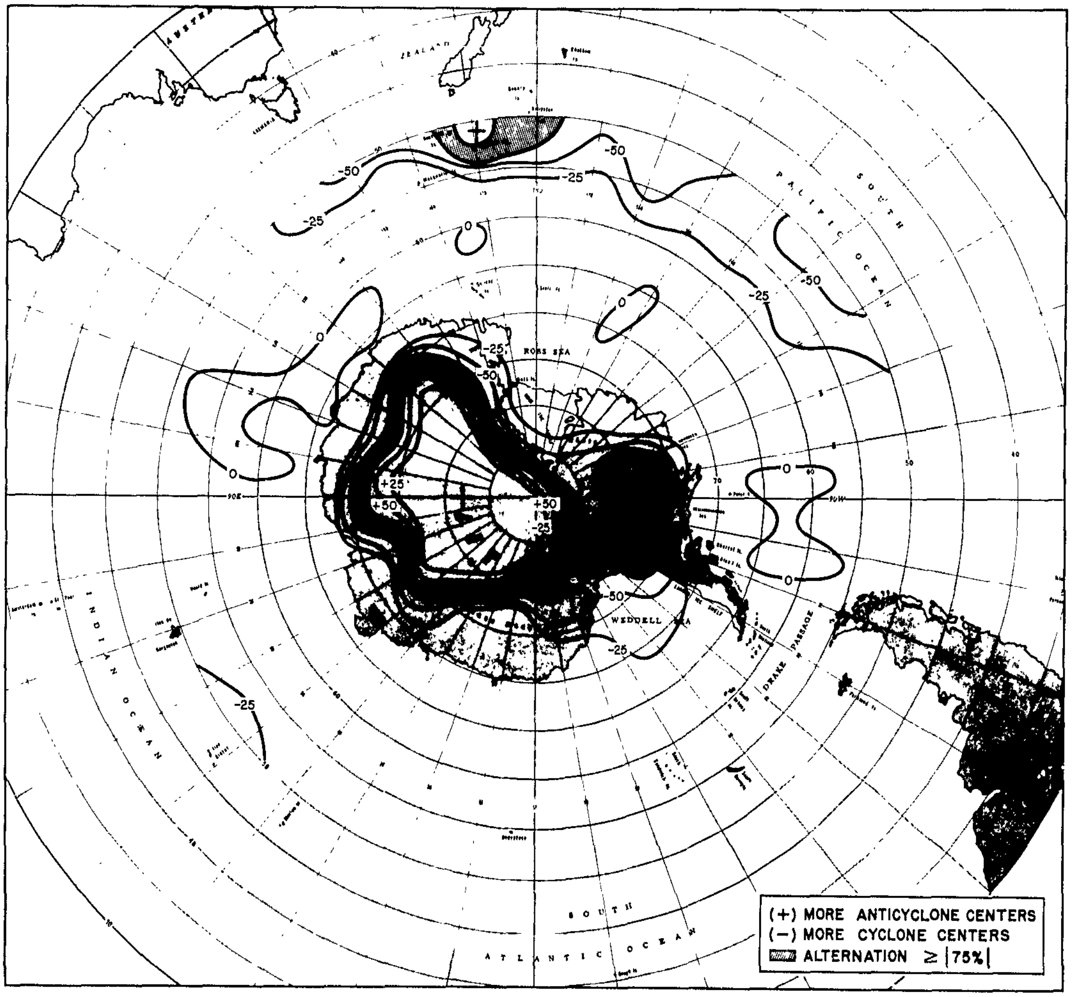

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